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PROGRAM MANAGER FOR
ROCKY MOUNTAIN ARSENAL

**U.S. ARMY
MATERIEL COMMAND** — COMMITTED TO PROTECTION OF THE ENVIRONMENT —

FINAL ECOLOGICAL RISK ASSESSMENT REPOR
SUBMERGED QUENCH INCINERATOR
TASK IRA-2
BASIN F LIQUIDS TREATMENT DESIGN

MARCH 1991

CONTRACT NO. DAAA15-88-D-0022/0001

VERSION 3.0

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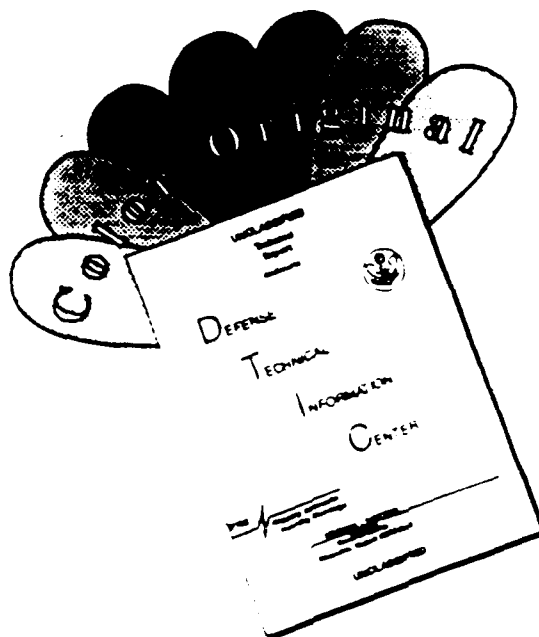DEC 17 1993

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FINAL ECOLOGICAL RISK ASSESSMENT REPORT
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MARCH 1991

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    THE OBJECTIVE OF THIS ECOLOGICAL RISK ASSESSMENT IS TO EVALUATE THE POTENTIAL IMPACTS OF ON-SITE INCINERATION OF BASIN F LIQUIDS. 29 CHEMICALS WERE EVALUATED FOR POTENTIAL ADVERSE EFFECTS TO TERRESTRIAL AND AQUATIC WILDLIFE AND VEGETATION ON RMA. BASED ON THIS ASSESSMENT, IT IS CONCLUDED THAT THE OPERATION OF THE SUBMERGED QUENCH INCINERATOR POSES NO QUANTIFIABLE RISKS TO THE WILDLIFE AND VEGETATION.
    THE ASSESSMENT IS DIVIDED INTO THE FOLLOWING SECTIONS:
        1. DESCRIPTION OF THE AREA - TERRESTRIAL AND AQUATIC ECOLOGY
        2. CONTAMINANTS OF CONCERN
        3. ECOLOGICAL EXPOSURE - DESCRIPTION OF CONTAMINANT TRANSPORT FROM INCINERATOR TO ENVIRONMENT
        4. ECOLOGICAL RISK - DEVELOPMENT OF RISK CRITERIA, RISK CHARACTERIZATION
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1.1 OBJECTIVE

The objective of this ecological risk assessment is to evaluate the potential impacts that chemical emissions from destroying Basin F liquids in a Submerged Quench Incinerator (SQI) may have on wildlife and vegetation on Rocky Mountain Arsenal (RMA). The approach used in this ecological risk assessment is that recommended by the U.S. Environmental Protection Agency's (EPA) 1989 Interim Report "Risk Assessment Guidance for the Superfund Volume II Environmental Evaluation Manual (U.S. EPA/540/1-89/01). The objective of an ecological assessment is to make a qualitative (or when data are available, quantitative) appraisal of the actual or potential effects that a waste management facility may have on plants and animals.

This ecological risk assessment is complimentary to the human risk assessment (WCC 1990). Many of the initial steps used to evaluate the human risks are applicable to this ecological assessment, for example: identifying contaminants of concern (indicator chemicals), and evaluating the release, migration, and fate of chemicals in the environment.

After these initial steps, the next steps in an ecological risk assessment are to identify potentially exposed habitats and wildlife populations, evaluate the chemical concentrations at these locations and characterize the potential for exposure and subsequent impacts. Both flora and fauna are considered potential receptors.

1.2 SCOPE OF EVALUATION

This ecological risk assessment is based on the modeled deposition of chemicals from the incineration of Basin F liquids at RMA. The scope of this evaluation was limited to consider only risks from the SQI emissions source and not to evaluate the SQI as a source in addition to all other surrounding sources of contamination at RMA. The data used as input to the model include chemical composition of pilot incinerator emission studies, design emission rates, and Stapleton meteorological data. The modeled concentrations were used to evaluate the risk to selected wildlife species. Field data or environmental samples were not utilized in this ecological assessment since the facility does not yet exist.

Because there are little toxicological data available for the specific RMA biota species that may be impacted by the identified chemicals of concern, it was necessary to rely on the existing scientific literature and to utilize the known toxicity of these chemicals on closely related species. The Biota Remedial Investigation (BRI) Final Report (ESE 1989) is the most current source of site-specific toxicological information. The BRI provides toxicity assessments for several indicator compounds selected for this ecological risk assessment and an evaluation of potential impacts to important RMA biota species; e.g., the bald eagle. The proposed BRI "no effects" criteria derived for plants and wildlife at RMA are used as acceptable concentrations in this ecological risk assessment. Quantitative assessments of the ecological risk resulting from particulate deposition of SQI emissions onto water, soil, and vegetation media are made through comparisons to the BRI "no effects" criteria. Although the BRI criteria are as yet only proposed and subject to revision under the on-going biota exposure assessment, they are the best RMA-specific criteria available for use in this agreement.

1.3 DESCRIPTION OF THE AREA

The following description of the area is based on existing RMA reports including: the BRI Report (ESE 1989); the Water Remedial Investigation (WRI) Report (MKE 1988); Study Area Reports (SARs) (EBASCO et al. 1989(a), 1989(b), EBASCO 1989a); Vegetation Resources of RMA (MKE 1989b); Wildlife Resources of RMA (1989a); Aquatic Resources of RMA (1989c); Prairie Dog Populations of RMA (ESE 1988); and the Bald Eagle Study (ESE 1989b).

1.3.1 Physical Environment

RMA lies in southern Adams County about 10 miles northeast of downtown Denver and just north of Stapleton International Airport. RMA covers about 27 square miles and is part of the High Plains physiographic province, which is characterized by low, gently-rolling terrain. The average elevation across RMA is 5,250 feet (ft) above mean sea level (msl), with an elevation range from 5,330 ft msl at the southeastern boundary to 5,130 ft msl at the northwestern boundary. Surface water flows within several small drainage basins that are tributaries of the South Platte River. Manmade structures, including diversion ditches, lakes, and water retention basins, have modified the natural drainage patterns.

Climate

The climate of the region is sunny and semi-arid. Precipitation at RMA is approximately 15 inches per year and relative humidities average about 50 to 60 percent monthly. Much of the precipitation falls as snow, while approximately 50 percent of the total annual precipitation falls between April and July. Frequent summer thunderstorms result in substantial localized variations in precipitation rates. Winters are relatively dry and desiccating high-intensity winds are common. Prevailing winds at RMA are from the south and southeast.

Geology and Soils

The surficial geological units at RMA consist of unconsolidated alluvial and eolian deposits, and the underlying geologic unit is the Cretaceous Denver Formation. Alluvial and eolian deposits locally attain a thickness of 130 ft but are typically less than 50 ft; areas with less than 20 ft are also common. Several prominent paleochannels have been identified in the erosional surface of the Denver Formation. Deposits within the paleochannels are generally coarse-grained, while fine-grained materials tend to occur over the entire area.

The Denver Formation underlying the alluvium consists of lenticular sandstone and siltstone bodies interlayered with relatively thick sequences of low permeability shale, claystone, and organic-rich lignitic beds. Low permeability volcaniclastic material is also present in the upper part of the Denver Formation. The thickness of the Denver Formation at RMA varies from 200 to 500 ft. Bedding planes in the Denver Formation dip approximately 1 degree to the southeast.

Soils at RMA include clayey soils on nearly level upland surfaces, especially in the northern portion of RMA; sandy eolian soils on rolling upland surfaces, especially in the southern portion of RMA; and loamy to sandy stratified alluvial soil on the floodplains and low terraces of drainages. The loamy soils are generally deep and well-drained, although runoff may be high and infiltration low so that available moisture is confined to the first 2 ft of soil during most of the growing season.

Surface Water Hydrology

Surface runoff across RMA generally flows northwest toward the South Platte River. The major drainage within RMA is First Creek, which drains an area of approximately 12 square miles within the RMA

boundaries. The Irondale Gulch basin drains an area of approximately 6.5 square miles within RMA's boundaries. Four manmade lakes and several other impoundments are located within the boundaries of RMA. Six basins, designated A through F, were constructed for retention of process waste, wastewater, and storm runoff. Each basin is a natural topographic depression that has been modified by berms and other structures.

The lakes and basins are fed by surface runoff, drainage and interceptor ditches, and poorly defined natural channels. The lakes and basins generally lose water to evaporation and to the unconfined groundwater flow. First creek also loses water to the unconfined groundwater system as it flows across the RMA.

1.3.2 Ecology

RMA contains a variety of terrestrial and aquatic habitats. While industrial land use dominates the central sections of RMA, lakes, wetlands, tree groves, and reservoirs are found in the southern and eastern sections. Native prairie remnants intermixed with disturbed vegetation types and areas replanted with crested wheatgrass (Agropyron cristatum) are predominant in the northern portions of RMA. RMA provides habitat for a diversity of wildlife including all the major common species and many of the lesser common species of the regional fauna. Because RMA is fenced and hunting and livestock grazing are excluded, an unusual variety and abundance of wildlife, including the endangered bald eagle (Haliaeetus leucocephalus), can be found.

1.3.2.1 Aquatic Ecology

The aquatic habitats on RMA are largely the result of human development. The largest of the aquatic habitats are the four reservoirs, known as the Lower Lakes, which are found in the southern half of RMA in Sections 1 and 2 (Figure 1-1). The Lower Lakes include Lower and Upper Derby Lakes, Lake Mary, and Lake Ladora. Storage capacity for the lakes varies from 60 acre-ft for Lake Mary to 970 acre-ft for Lower Derby Lake.

North Bog

■ Proposed SQI

Toxic
Storage
Yard
Pond

Lake
Ladora

Lower
Derby
Lake

Upper
Derby
Lake

Lake
Mary

First Creek

Rod and Gun
Club Pond

Haváná
Ponds

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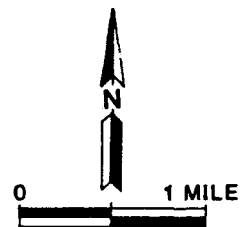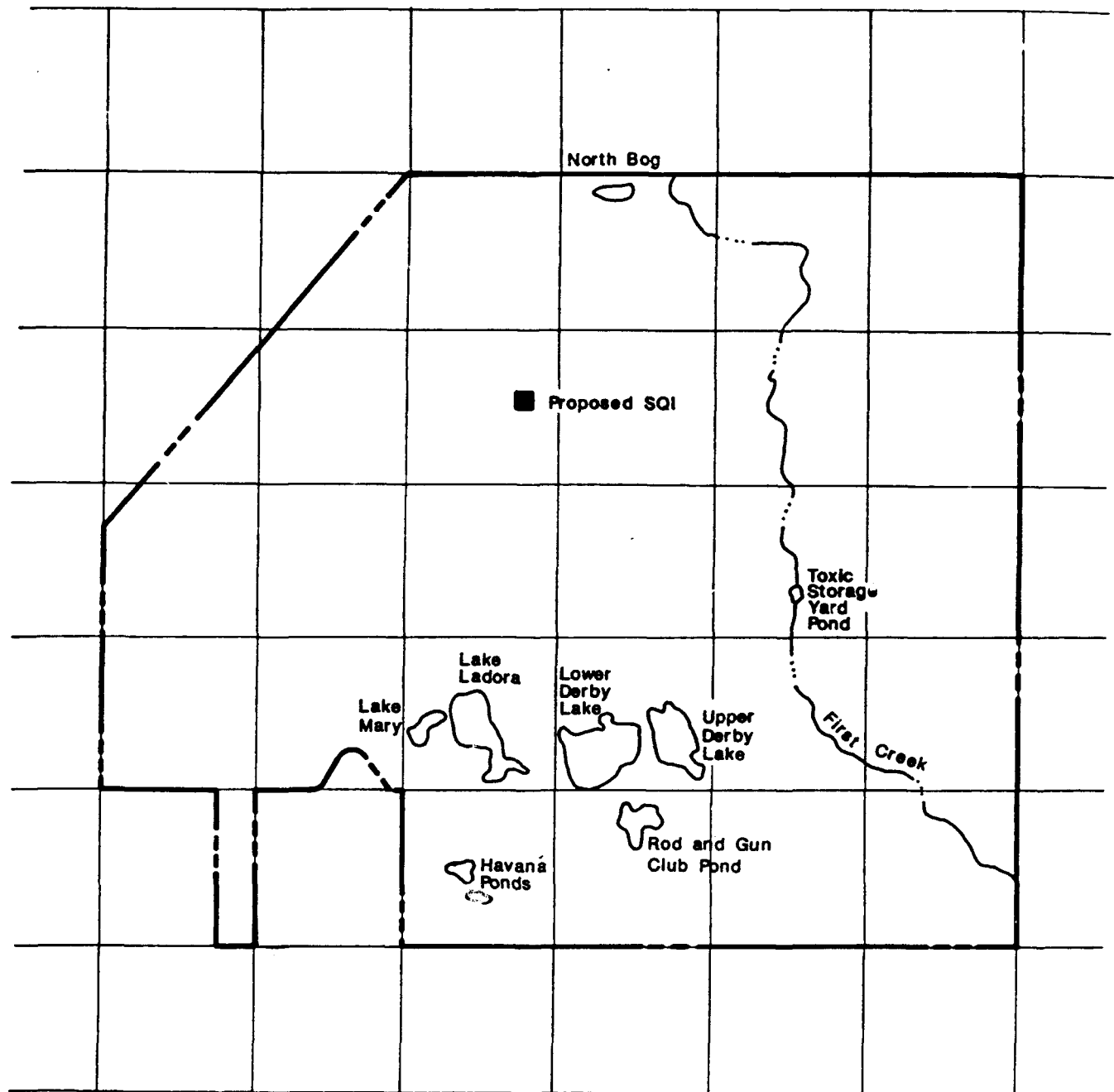
Job No. : 2001-375	WATER BODIES ON RMA
Prepared by : J.J.A.	
Date : 4/20/90	Figure 1-1

Lower Derby Lake is the largest reservoir, with a surface area of about 93.9 acres and an average depth of 6 to 9 ft. It receives inflow from Irondale Gulch basin (including Upper Derby Lake), the Uvalda Interceptor, the Highline Lateral, as well as runoff from the South Plants.

Upper Derby Lake is used only for flood and overflow storage and is dry most of the year, except during the spring. The lake when full has a surface area of about 84 acres and an average depth of less than 6 ft. The rooted vegetation and broad, shallow nature make Upper Derby Lake suitable for breeding by frogs and toads.

Lake Ladora is the second largest lake with a surface area of about 62 acres. The deepest area of Lake Ladora exceeds 15 ft, but the average depth is less than 6 ft due to extensive shallow areas. Lake Mary is the smallest of the lakes with a surface area of 7.9 acres and an average depth of 8.4 ft.

A number of fish and invertebrate species have been collected from Lake Mary, Ladora, and Lower Derby. Fish species that have been collected include northern pike (Esox lucius), largemouth bass (Micropterus salmoides), bluegill (Lepomis macrochirus), black bullhead (Ictalurus melas), channel catfish (Ictalurus punctatus), and carp (Cyprinus corpio). Aquatic invertebrates that have been collected include dragonflies, damselflies, chironomids, crayfish, and snails. Common aquatic macrophytes that can be found in the lakes include pondweed (Potamogeton spp.), and northern water-milfoil (Myriophyllum exalbescens).

Several other small manmade ponds are found on RMA. These include the Rod and Gun Club Ponds in Section 12, the Havana Pond in Section 11, and the Toxic Storage Yard Pond in Section 31. The Rod and Gun Club Pond covers about 4.9 acres and is 'ess than 3 ft deep. It has no drainage outlet and receives runoff primarily from the surrounding terrain, although an overflow ditch can carry water to it from Lower Derby Lake. The Rod and Gun Club Pond provides a breeding habitat by frogs and toads and has been described as an important breeding area for water fowl. The Havana Pond is a small impoundment that supports large breeding populations of frogs and toads in the spring and attracts abundant numbers of waterfowl during migration periods. It receives water from the Havana Street Interceptor and Peoria Ditch and sheet runoff from adjacent areas. The Toxic Storage Yard Pond, a small pond situated along First Creek and covering less than 0.5 acres, is also a breeding habitat for frogs and toads.

Two natural water bodies, First Creek and the North Bog, are also found on RMA. First Creek, which is located in the eastern half of RMA, is considered the largest and ecologically most important surface drainage on RMA. First Creek is a fairly persistent intermittent stream which in dry years flows only during

the spring or following major storms. Several canals and ditches contribute surface water to First Creek. It also receives effluent from the on-site RMA sewage treatment plant and overflow water from Upper Derby Lake. First Creek supports some fish life including the plains killifish (Fundulus Kansae), fathead minnow (Pimephales promelas), and green sunfish (Lepomis cyanellus). Well-developed hydrophytic and phreatophytic vegetation occur along most of its length.

The North Bog, which was made into a small pond through impoundments and barriers, covers approximately 1 acre or less in Section 24. The North Bog is fed by groundwater which rises to the surface and water discharged from the North Boundary Containment System. The pond supports breeding populations of frogs and toads. Numerous fathead minnows have been captured in the pond. Reports from USFWS indicate carp have also been observed in the pond. Contamination has been reported in the North Bog Pond which is believed to be due to seepage from contaminated Basins in Section 26 which flows up through the North Bog Pond.

Other than First Creek, the only bodies of flowing water entering RMA are various canals and ditches entering from the south which deliver water to the lakes and interceptors. These include the Highline Lateral and Uvalda Interceptor, the Havana Street Interceptor and Peoria Ditch, and the Sand Creek Lateral. The Havana Street interceptor and Peoria Ditch deliver water to Havana Pond. The Uvalda Interceptor and Highline Lateral deliver water to Lower Derby Lake. Sand Creek Lateral diverts water from Havana Pond and Lower Derby Lake during periods of high water level, collects additional runoff from the South Plants Area, and flows north out of the Irondale Gulch drainage toward First Creek. These ditches and canals have irregular flow and represent limited aquatic habitat.

1.3.2.2 Terrestrial Ecology

Flora

RMA is an area of low, rolling terrain characterized by grasslands, rabbitbrush (chrysothamnus nauseosus) shrublands, small stands of plains cottonwoods (Populus deltoides) and peachleaf willows (Salix amygdaloides), cattail (Typha spp.) marshes, extensive weedy areas, and areas of ornamental trees and shrubs. Most of the habitat at RMA is open, grassland areas dominated by xeric, short grass species, such as blue grama (Boutelova gracilis) and cheatgrass (Bromus tectorum). Mid-grass speci-- such as western wheatgrass (Agropyron Smithii) and tall-grass species such as big bluestem (Andropogon gerardi) are found in the more mesic areas. Plains cottonwood and peachleaf willow are the dominant tree species in the

riparian woodlands; the dominant shrub species on RMA include rubber rabbitbrush (chrysothamnus nauseosus) and broom snakeweed (Gutierrezia sarothrae).

Five broad community types dominate the vegetation at RMA: weedy forbs, cheatgrass/weedy forbs, cheatgrass/perennial grassland, native perennial grassland, and crested wheatgrass (Figure 1-2). Production and coverage values for each community type are presented in the BRI (ESE 1989) and Vegetation Resources of RMA (MKE 1989b) reports. The cheatgrass/weedy forb community is the most extensive vegetation type, covering approximately 3830 acres or about 22 percent of RMA. Mean total vegetation cover for this type is 45.8 percent, with 4.9 percent bare soil and 49.3 percent litter (remnants of previous year's growth). Mean biomass production is 140.3 grams per square meter (g/m^2) on a dried weight basis.

The cheatgrass/perennial grassland covers about 1908 acres or 11 percent of RMA. This community type which is similar to the preceding cheatgrass/weedy forb community type, has a total vegetative cover of 40.3 percent, with 3.9 percent bare soil and 55.8 percent litter. Total annual biomass production is about 104.2 g/m^2.

About 13 percent or 2174 acres of RMA are covered by the weedy forb [Kochia iranica/field bindweed (Evolvulus nuttallianus or Convolvulus arvensis)] community type. Field bindweed is the most prevalent forb in the prairie dog towns. Total annual biomass production for this community type averages 121 g/m^2 on a dried weight basis, and total vegetation cover is 29.6 percent with 21.8 percent bare soil and 48.6 percent litter.
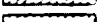
Native perennial grassland covers about 3420 acres or 20 percent of RMA. The largest area of native grassland is near the west-central portion of RMA. Mean total vegetative cover by this community type is 34.5 percent, with 8.6 percent bare soil and 56.9 percent litter. Total biomass production for this type is 96.7 g/m^2 on a dried weight basis, which is the lowest production of all the community types.

Stands of crested wheatgrass cover about 19 percent or 3252 acres on RMA. Mean total cover for this type is 28.5 percent, with 4.7 percent bare soil. Litter consisting of the previous years growth comprises about 66.8 percent of the total ground cover. Mean annual biomass production of this community type is about 83 g/m^2.
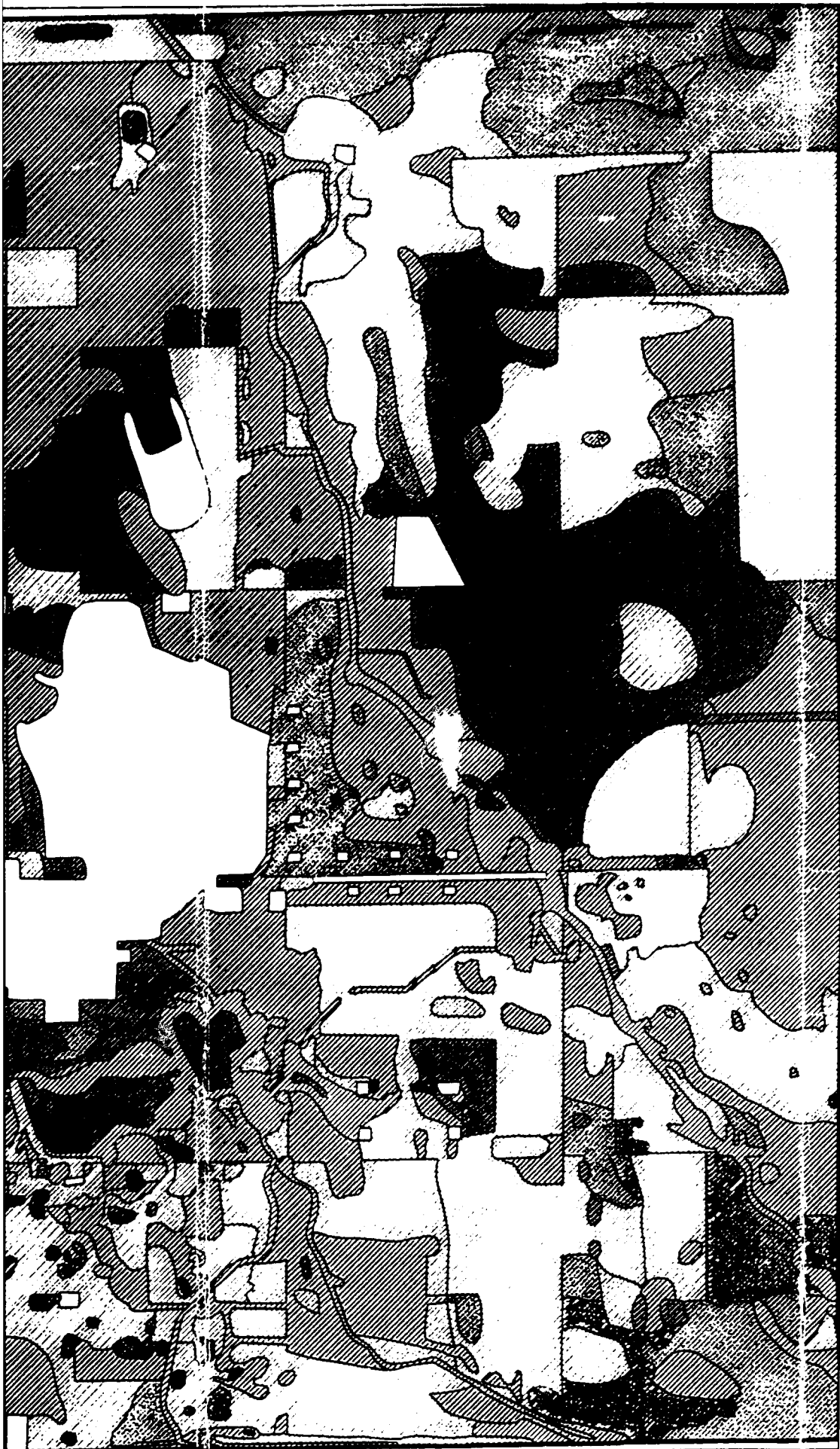
MAP LEGEND

- ■ WEEDY FORB
- ▨ CHEATGRASS/WEEDY
- ■ CHEATGRASS/PEREN
- ▦ NATIVE PERENNIAL (
- ▢ CRESTED WHEATGRA
- ■ MINOR VEGETATION
- ▨ WETLAND/RIPARIAN
- ■ WATER
- ▢ UNVEGETATED

N

0   3000

SCALE IN FEET

Figure 1-9
VEGETATION MAP OF R(
MOUNTAIN ARSENAL
SOURCE: MKE. 1988

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U.S. Army Program Manage
For Rocky Mountain Arsena

Aberdeen Proving Ground, Maryl

MAP LEGEND

WEEDY FORB
CHEATGRASS/WEEDY FORB
CHEATGRASS/PERENNIAL GRASS
NATIVE PERENNIAL GRASS
CRESTED WHEATGRASS
MINOR VEGETATION TYPES
WETLAND/RIPARIAN
WATER
UNVEGETATED

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SCALE IN FEET
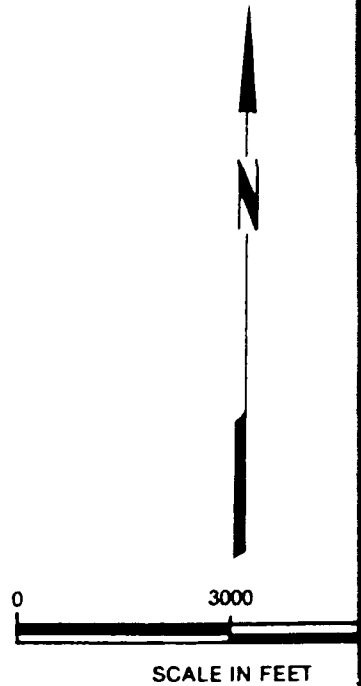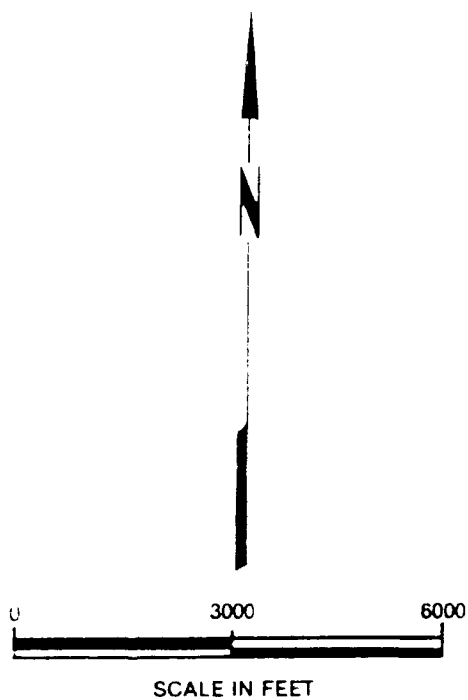
Figure 1-9

VEGETATION MAP OF ROCKY
MOUNTAIN ARSENAL

SOURCE: MKE, 1988

Prepared for:
**U.S. Army Program Manager's Office
For Rocky Mountain Arsenal**

Aberdeen Proving Ground, Maryland

3-63

Other minor community types and their approximate coverage of RMA include: sand sagebrush (Artemisia filifolia) shrubland -247 acres (1.5 percent); rubber rabbitbrush shrubland - 57 acres (0.3 percent); yucca (Yucca glauca) grassland - 138 acres (0.8 percent); locust (Gleditsia triacanthos) thickets - 89 acres (0.5 percent); cottonwood/willow stands - 165 acres (1 percent), bottomland meadows - 467 acres (2.6 percent); and cattail marshes - 133 acres (0.8 percent).

Fauna

The most conspicuous mammal on RMA is the black-tailed prairie dog (Cynomys ludovicianus), whose colonies in recent years have occupied over 5000 acres or 30 percent of the RMA acreage (Figure 1-3) (ESE 1988a). Since August 1988, most of the prairie dog colonies on RMA have experienced catastrophic losses due to sylvatic plague. The largest single prairie dog complex on RMA, the population east of First Creek, was essentially decimated by the plague. Because prairie dogs were the major prey for bald eagles, ferruginous hawks (Buteo regalis) and other raptors at RMA, efforts have been undertaken to reestablish the RMA prairie dog population through transplants. Other common RMA rodents include the thirteen-lined ground squirrel (Spermophilus tridecemlineatus) in open habitats, fox squirrels (Spermophilus niger) in riparian habitats, muskrats (Ondatra zibethicus) on all permanent bodies of water, and pocket gophers (Geomys bursarius). Cottontails (Sylvilagus spp.) and jackrabbits (Lepus spp.) are abundant across RMA.

Mule deer (Odocoileus hemionus) and white-tailed deer (Odocoileus virginianus) are the most conspicuous of the larger RMA mammals. Of the carnivores, coyotes (Canis latrans) are the most conspicuous, particularly in and around the prairie dog towns. Other RMA carnivores include badgers (Taxidea taxus), red fox (Vulpes vulpes), gray fox (Urocyon cinereoargentens), swift fox (Vulpes velox), raccoon (Procyon lotor), striped skunk (Mephitis mephitis), and long-tailed weasel (Mustela frenata).

RMA has harbored an unusually high density of raptors due to abundance of prey, particularly the prairie dog, the distribution and abundance of suitable nesting and perching habitat, and the relative lack of human disturbance. Of the 17 species of hawks and owls observed on RMA, two species of high federal interest, the endangered bald eagle and the ferruginous hawk, have been found in notably large numbers on RMA in recent years during the winter months. During the winters of 1988 and 1989, more than 20 bald eagles were found roosting in a mature cottonwood stand in the Eastern Study Area of RMA. Although bald eagles primarily feed on fish, they are opportunists, and at RMA have been observed to feed largely on prairie dogs, rabbits, and carrion, many of which are stolen from the ferruginous hawks. Feeding

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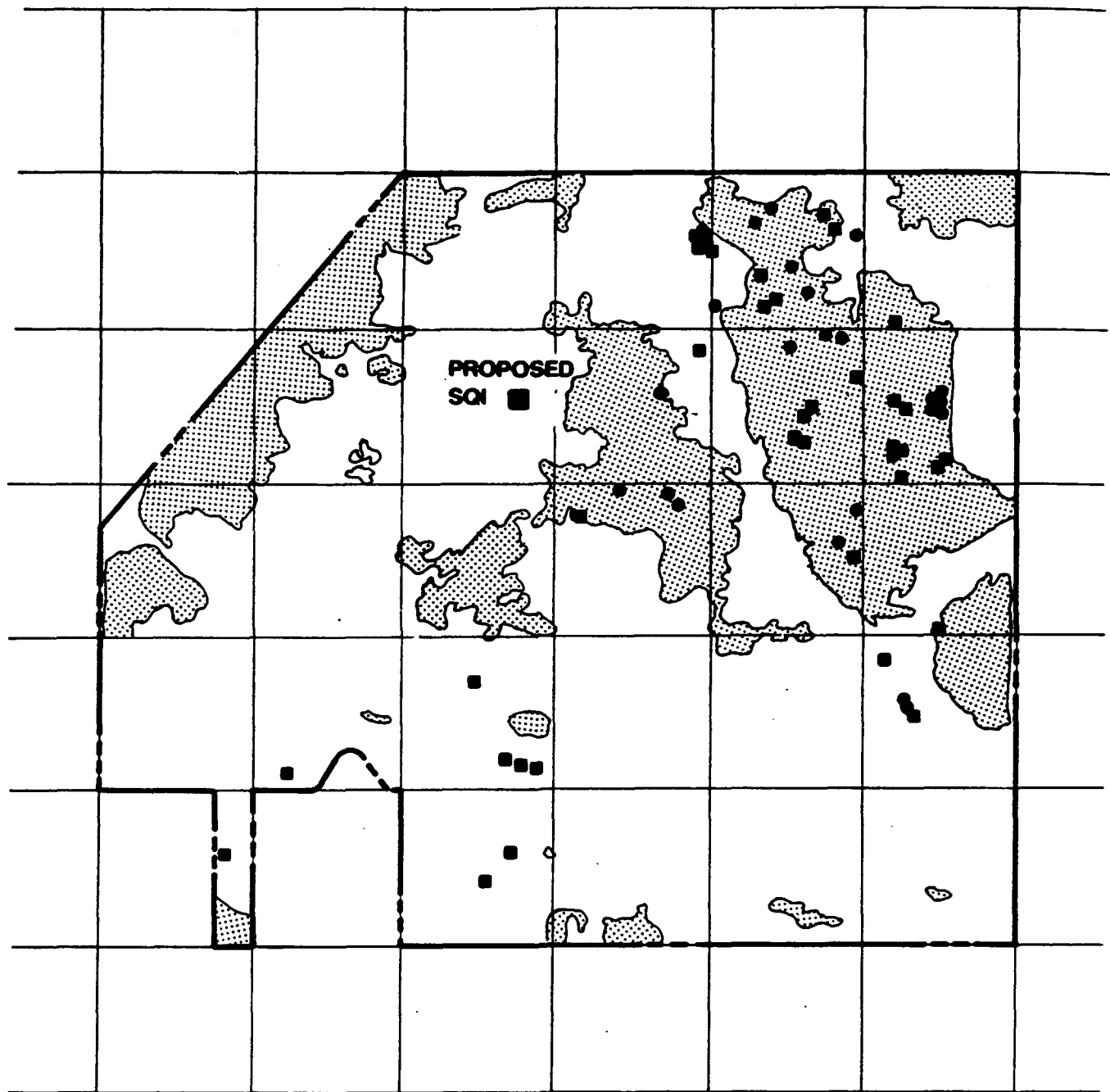
LEGEND

PRAIRIE DOG COLONY RANGE

■ EAGLE FEED OBSERVATION
(87-88 Winter)

● EAGLE FEED OBSERVATION
(86-87 Winter)

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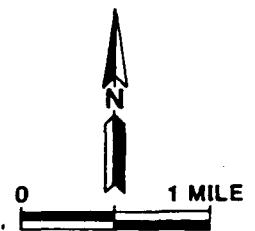
Job No. : 2001-375	RMA PRAIRIE DOG COLONIES AND BALD EAGLE FEEDING OBSERVATIONS
Prepared by : J.J.A.	
SOURCE: ESE 1989 Date : 4/20/90	Figure 1-3

observations of the RMA bald eagle population from 1987 through 1988, showed that the black-tailed prairie dog was the eagles' most frequent prey (ESE 1988b). Figure 1-3 shows the observed bald eagle feeding locations in relation to the prairie dog colony locations for winter 1986 through winter 1988.

Hawk roosts are located in large trees across RMA. Rough-legged hawks (Buteo lagopus), red-tailed hawks (Buteo jamaicensis) and golden eagles (Aquila chrysaetos) as well as Swainson's hawks ((Buteo swainsoni), northern harriers (Circus cyanens), American kestrels (Falco sparverius), and great-horned owl (Bubo virginianus), long-eared owl (Asio ofus), and burrowing owls (Athene cunicularia) are also common on RMA. Less common raptors in the area include Cooper's hawks (Accipiter cooperii), sharp-skinned hawks (Accipiter straiatue), short-eared owl (Asio flammeus), prairie falcons (Falco mexicanus), merlins (Falco columbarius), and occasionally turkey vultures (Cathartes aura)and osprey (Pandion haliaetus).

Hawks, eagles, kestrels, and the burrowing owl often concentrate near prairie dog towns and other open habitats, while owls are more often observed near woodlands, buildings and warehouses. The recent decline in the prairie dog population due to plague, has contributed substantially to changes in overall area use by the bald eagle and other raptors.

Numerous songbirds are attracted to the diverse RMA habitats. Different species are found according to their preferred habitat for nesting and feeding. These habitats include the open grassland, weedy forb, and shrub habitats; the mature deciduous trees; the marshy areas and riparian woodlands; the ornamental and shade trees near buildings; and the abandoned buildings.

Snakes, frogs, and lizards are also common on RMA. The most conspicuous RMA reptiles are the bullsnakes (Pituophis melanoleucus), while the most abundant amphibian is the northern chorus frog (Pseudacris triseriata). Turtles have not been reported on RMA.

Waterfowl

Waterfowl are commonly observed on RMA along First Creek and around the Lower Lakes. Canada geese (Branta canadensis) are the most abundant waterfowl observed feeding and nesting on RMA. A variety of both dabbling and diving ducks have been observed nesting and feeding on RMA, particularly in the vicinity of the Lower Lakes. Wading birds, such as the great blue heron (Ardea herodias) and the black-crowned night heron (Nycticorax nycticorax) are commonly observed feeding in the shallows of the Lower Lakes, Havana Pond, and the marshy areas along First Creek. Lake Ladora receives the greatest use by migrating

diving ducks and Lower Derby Lake is less heavily used. Both gulls and shorebirds are common on RMA.
Other water birds observed on RMA include white pelicans (_Pelecanus erythrorhynchos_) and double-crested
cormorants (_Phalacrocorax auritus_).

2.1 INDICATOR CHEMICAL SELECTION PROCESS

The selection of indicator compounds is the first step in an ecological risk assessment. The objective of selecting indicator compounds is to identify a subset of chemicals that represent those chemicals that are the most toxic, environmentally mobile, environmentally persistent, and that would potentially occur in the greatest concentrations. One source of indicator chemicals for this analysis was the indicator chemicals selected in the human risk assessment. A second source was the analytical data collected for environmental media (water, air, sediment, and biota) during the RMA Remedial Investigation.

The first step in selecting indicator chemicals is to identify potentially toxic chemicals and their concentrations in the stack emissions from the pilot incinerator tests, so that indicator scores can be calculated. This step was originally done in the human risk assessment (WCC 1990). Chemicals selected in the human risk assessment were evaluated on the basis of the chemicals' environmental fate and transport characteristics and the prevalence of particular chemicals in the Basin F fluid. Parameters such as Log Kow and Fish BCF, which indicate the potential for chemicals to bioaccumulate in the food chain were also considered.

2.1.1 Chemicals Selected From the Human Risk Assessment

All chemicals except volatiles that were selected as indicator chemicals in the human health risk assessment were considered for inclusion in the ecological risk assessment. These chemicals are listed in Table 2-1. Chemicals selected from the human health risk assessment for inclusion in this risk assessment are shown in Table 2-2. Chemicals eliminated in the human health risk assessment because of a low indicator score, were reconsidered as part of this ecological risk assessment. Summaries of the physical, chemical, and environmental fate data for chemicals considered in the human risk assessment that were selected for inclusion in this risk assessment are presented in Table 2-3.

The chlorodibenzodioxins and chlorodibenzofurans were included as indicator chemicals in the human risk assessment as well as this ecological risk assessment because they are potential incineration products as well as potent carcinogens. Dieldrin, arsenic, and antimony were also considered as indicator compounds in the

TABLE 2-1
Chemicals Considered in the Ecological Risk Assessment

	HRA[1]	BRI[2]	BF[3]	ERA[4]
Aldrin	x		x	x
Allyl chloride		x[6]		
Aluminum		x		
Ammonia		x		
Antimony	x[5]		x	x
Arsenic	x[5]	x[6]	x	x
Atrazine			x	x
Azodrin			x	
Barium	x	x	x	
B2EHP	x		x	
Benzene	x		x	
Beryllium	x[5]			x
Boron			x	
Bromomethane			x	
Cadmium	x	x	x	x
Calcium			x	
Carbon tetrachloride	x			
Chlordane/oxychlordane		x		
Chloride			x	
Chlorobenzene			x	
Chloroform	x	x	x	
Chromium	x		x	x
Cobalt			x	
Copper	x	x	x	x
CPMS		x		
CPMSO		x	x	x
CPMSO2		x	x	x
Cyanide			x	
DBCP		x[6]		
DCPD		x		
DDE	x[5]	x	x	x
DDT	x[5]	x	x	x
Dieldrin	x[5]	x[6]	x	x
Dimethyldisulfide			x	
DIMP		x	x	x
Dioxins	x[5]		x	x
Dithiane		x	x	x
DMMP		x	x	x
DNBP	x			x
Endrin		x[6]	x	x
Ethylbenzene	x	x		
Fluoride			x	
Furans			x	

TABLE 2-1 (continued)

	HRA[1]	BRI[2]	BF[3]	ERA[4]
Iron	x		x	
Isodrin		x[6]	x	x
HCCPD			x	
Heptachlor		x		
Lead (Inorganic)	x	x	x	
Magnesium			x	
Malathion		x	x	x
Manganese			x	
Mercury (Inorganic)	x	x[6]	x	x
Methylene chloride	x			
Methyl parathion		x		
Methyl phosphonic acid		x		
Molybdenum		x		
Mustard				
Nickel	x	x	x	
Nitrate			x	
Nitrogen			x	
4-Nitrophenol			x	
Nitrosodimethylamine		x		
1,4-Oxathiane		x		
Parathion		x	x	x
PCBs		x		
Phosphorus (total)			x	
Potassium			x	
Silver	x		x	
Sodium		x		
Sulfate		x		
Supona		x		
Vanadium			x	
Vapona		x		
Thallium	x		x	
Toluene	x	x	x	
1,1,1 Trichloroethane	x			
Trichloroethylene		x		
Urea			x	
Xylene	x	x		
Zinc			x	

[1] HRA = Chemicals detected in stack emissions test and considered in the Human Risk Assessment-includes both carcinogens and noncarcinogens (WCC, 1990, Table 2-1 and 2-2)

[2] BRI = Chemicals considered in the BRI (ESE, 1989)

[3] BF = Chemicals found in the Basin F liquid (WCC, 1989)

[4] ERA = Chemicals selected for inclusion in the Ecological Risk Assessment

[5] Chemical not detected in stack gas emissions, but included in the Human Risk Assessment to ensure that health risks are not underestimated.

[6] Major contaminant of concern in BRI (ESE, 1989)

TABLE 2-2
INDICATOR CHEMICALS

Chemicals Selected from the Human Risk Assessment for Inclusion in the Ecological Risk Assessment:

semi-volatiles	concentrations in Basin F liquid[1]
aldrin[2]	23.8 - 2900 ppb
B2EHP[3]	--
DNBP[3]	--
dieldrin[2]	5.0 - 300 ppb
DDT	340 ppb
DDE	109 ppb
dioxins[4]	--
furans[4]	--

metals	
arsenic[2]	1.0 - 8 ppm
antimony	0.6 - 1.1 ppm
barium	0.4 ppm
beryllium[3]	--
cadmium	8.4 - 2000 ppb
chromium	85 - 1900 ppb
copper	210 - 5200 ppm
lead	74 - 2000 ppb
nickel	31 - 34 ppm
silver[3]	--
mercury[2]	26 - 340 ppb
thallium[3]	--

Additional Chemicals Selected From the BRI Report for Inclusion in the Ecological Risk Assessment:

semi-volatiles	Concentrations in Basin F liquid[1]
CPMSO	1000 - 20,000 ppb
CPMSO2	1000 - 200,000 ppb
Dithiane	5.0 - 100 ppb
DIMP	<0.1 - 123 ppm
DMMP	500 - 760 ppm
endrin[2]	˙ 98 - 596 ppb
isodrin[2]	2.0 - 1980 ppb
malathion	810 ppb
parathion	110 ppb

---

[1] range of concentrations reported in Basin F liquid (WCC, 1989)

[2] Major contaminants of concern in BRI Report (ESE, 1989)

[3] Detected in WCC stack emissions tests

[4] Not detected in SQI emissions tests, but considered to be a possible component of emissions

TABLE 2-3
Physical, Chemical, and Environmental Fate Data

	Mole Weight (g/mole)	Water Solubility (mg/l)	Vapor Pressure (mm Hg)[1]	Henry's Law Constant (atm-m³/mol)	Koc[2] (ml/g)	Log Kow[3]	Fish BCF[4] (l/kg)
Aldrin	365	1.80E-01	6.00E-06	1.60E-05	96000	5.30	28
B2EHP	391						
DNBP	278	1.30E+01	1.00E-05	2.82E-07	170000	5.60	
CPMSO[5]	175	1.05E+03 to 1.20E+03	8.0E-04 to 2.5E+00	1.5E-07		1.26-1.33	
CPMSO2[5]	191	1.05E+03 to 1.17E+03	5.0E-04 to 2.5E+00	1.2E-07 to 4.29E-06		1.20	
Dieldrin	381	1.95E-01	1.78E-07	4.58E-07	1700	3.50	4760
DDT	355	5.00E-03	5.50E-06	5.13E-04	243000	6.19	54000
DDE	318	4.00E-02	6.50E-06	6.80E-05	44000000	7.00	51000
DIMP[5]	180	1.5E+03	2.8E-01 (25C)	1.9E-04		1.73-1.82	
DMMP[5]	124	8.0E+05	6.2E-01 to 8.7E-01 (25C)	NA		1.8	
Dithiane[5]	120	3.0E+03	8.0E-01 (25C)	NA		0.77	
Endrin[5]	381	2.4E-02 to 2.5E-01	2.0E-07 to 2.7E-07 (25C)	4.4E-07 to 4.2E-06		3.21-5.34	
Furan	68						
Isodrin[5]	365	2.0E-02 to 1.4E+00	<1.0E-04 (25C)	3.4E-05 to 3.2E-03		6.51	
Malathion[5]	330	2.45E-05 (25C) to 1.45E+02	4.0E-05 (30C)	9.0E-08 to 1.2E-07		2.36-2.89	
Parathion[5]	291	2.0E+01 to 2.4E+01	5.7E-06	7.9E-07 to 1.1E-06		3.8-3.9	

TABLE 2-3 (continued)

	Mole Weight (g/mole)	Water Solubility (mg/l)	Vapor Pressure (mm Hg)[1]	Henry's Law Constant (atm-m^3/mol)	Koc[2] (ml/g)	Log Kow[3]	Fish BCF[4] (l/kg)
Dioxins (2,3,7,8,-TCDD)	322	2.00E-04	1.70E-06	3.60E-03	33000000	6.72	5000
METALS							
Arsenic	75		0.00E+00	NA			44
Antimony	122		1.00E+00	NA			1
Barium	137			NA			
Beryllium	9		0.00E+00	NA			
Cadmium	112		0.00E+00	NA			81
Chromium	52		0.00E+00	NA			16
Copper	64		0.00E+00	NA	76	0.99	200
Lead	207		0.00E+00	NA			
Nickel	59		0.00E+00	NA			47
Silver	108		0.00E+00	NA			3080
Mercury	201		2.00E-03	NA			5500
Thallium	204		0.00E+00	NA			

(1) temperature given for values not reported by EPA
(2) Koc = Organic carbon-based partition coefficient
(3) Kow = Octanol/water partition coefficient
(4) BCF = Bioconcentration Factor
(5) Range of Values reported by EBASCO (July 1989)
NA = Not Available
Source: SPHEM (EPA, 1986)

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human risk assessment and this risk assessment due to their presence in the Basin F liquid, even though they were not detected in the stack emissions during pilot incineration tests. Silver, beryllium, and thallium, which were found in the stack emissions test but either not reported or tested for in the Basin F liquid, were also included in the human and ecological risk assessments. The trace levels of these elements found in the pilot emissions tests are believed to be due to a breakdown of processing components (e.g., pumpheads or metal piping).

2.1.2 Chemicals of Importance in the Biota Remedial Investigation

The 39 contaminants of concern that were identified in the BRI study were also considered for inclusion in this ecological risk assessment (Table 2-1). The 39 contaminants of concern were selected for evaluation in the BRI Report based on the following criteria (ESE 1989):

- Present in the RMA environment above ambient concentrations;

- Rated at least moderately toxic; and

- Volume and persistence information indicated that the chemical was present in the
  RMA environment in sufficient quantity and/or for a long enough period of time to
  pose a potential hazard to biota.

Of the 39 contaminants, 7 contaminants (aldrin/dieldrin, arsenic, dibromochloropropane (DBCP), endrin/isodrin, and mercury) were identified as major contaminants of concern to biota based on the following criteria (ESE 1989):

- Found in elevated levels in biota based on past studies;
- Found in the physical environment for biota at RMA based on current studies;
- Occurred in high volumes and/or with an areal extent of greater than 5 acres; and
- Occurrence/concentration in tissues could be related to known adverse effects.

Only the BRI contaminants that were found in the Basin F liquid or were identified in pilot incineration stack emissions were included in this ecological risk assessment. This includes six of the seven major contaminants of concern and several of the minor contaminants of concern (Table 2-2). DBCP was not included on the ecological indicator list as it was not detected in the Basin F liquids or stack emissions.

Minor contaminants of concern that were identified in the Basin F liquid and added to the ecological indicator list include: dithiane, malathion, parathion, chlorophenylmethylsulfoxide (CPMSO), chlorophenylmethylsulfone (CPMSO2), diisopropylmethylphosphonate (DIMP), and dimethylmethylphosphonate (DMMP). The physical, chemical, and environmental fate data of chemicals added to the ecological risk assessment from the BRI study are shown in Table 2-3.

2.2 INDICATOR CHEMICALS SELECTED FOR THE ECOLOGICAL RISK ASSESSMENT

The 29 chemicals selected for this ecological risk assessment are shown in Table 2-2. Seventeen semi-volatile compounds and 12 metals were selected. Volatile compounds such as trichloroethylene (TCE), toluene, and xylene which were considered in the human risk assessment were not included in the ecological risk assessment as soil or water deposition was assumed to be negligible. Volatile chemicals are assumed to remain in the gaseous form and become transported from the RMA site. The range of detected concentrations of the selected chemicals in the Basin F fluid is also presented in Table 2-2.

This section of the report describes how chemicals are transported from the SQI stack into the environment. There are four basic elements in determining ecological exposure: the environmental transport pathway, identifying exposure points, determining the chemical concentration at the exposure point, and determining the route or exposure pathway of chemical intake for the wildlife species. These distinct elements, which are all necessary in order for wildlife species to be exposed to the chemicals, are discussed in the following sections.

3.1 ENVIRONMENTAL TRANSPORT PATHWAYS

An exposure or environmental transport pathway is the mechanism by which chemicals are transported from a source to a wildlife receptor. In this ecological risk assessment the source is the stack emissions that will be released during the SQI incineration of Basin F liquids at RMA. This ecological risk assessment is limited to this single source and does not consider the presence of other existing sources for the same chemicals whether on-site or off-site.

The emissions from the SQI stack will be either solid particulates on which chemicals were adsorbed during particulate formation, or volatile chemicals which are assumed to remain in the gaseous phase. These gaseous and solid phases will be transported from the source through the air. The direction and distance of transport are dependent on site-specific meteorology and size distribution of the particulate matter. Gaseous phase chemicals will be transported away from the site and are assumed not to accumulate at the site. The distance that particulate matter is transported from the source is dependent on particulate size. Larger particulate will settle to the surface more quickly and closer to the source than smaller particulate. The meteorological conditions of the site (wind velocity and direction) will determine the spatial distribution of the settled particulates.

It is assumed that the particulates will settle on soil, vegetation, and surface water. These three media are the most important transport pathways for the chemicals from the source to the receptors. Other media, such as air and groundwater, were not considered important exposure media for biota in both the BRI and this ecological risk assessment. Sediment and water were considered as an integrated exposure media in this

risk assessment according to EPA guidance (SEAM 1988). EPA risk assessment guidance treats water and sediment as a "single" media because of the complex chemical equilibrium between the sediment and water.

3.2 EXPOSURE POINT IDENTIFICATION

The exposure locations or areas of concern in this ecological risk assessment are the points where wildlife receptors can potentially contact the media (soil, water, or vegetation) on which SQI particulate are deposited. Wildlife that may contact the air medium are not considered at risk in this ecological assessment, and the air medium is not evaluated as an exposure medium. The risks to wildlife from air exposure are minimal, as is discussed in Section 4.2, Risk Characterization.

3.2.1 Soil

Soil is an important exposure medium in this ecological risk assessment. The selection of exposure points for soil was based on those locations which are most ecologically significant in terms of important wildlife species, such as the bald eagle, American kestrel, and their food chains. Prairie dogs contact the soil media directly through ingestion and indirectly through burrowing. Prairie dogs are also reported to be the eagles' most frequent prey item (ESE 1988). Because prairie dogs are in continuous contact with soil and are an important link in the bald eagle food web, the prairie dog colony location which had the highest potential exposure and where eagles were likely to be feeding was selected as the most significant soil receptor location for initial consideration in this risk assessment.

A second location selected for the soil medium was the area of maximum particulate deposition. This area as modeled is approximately 150 ft by 150 ft square. It was conservatively assumed that prairie dogs were present at this location in order to evaluate the maximum ecological risk from the soil medium through prairie dogs to the bald eagle. The approach used in this risk analysis follows BRI Methodology in that the safe or "no effects" levels developed for soils are protective of all fauna, such as prairie dogs, as well as raptors such as the Bald eagle and American kestrel.

3.2.2 Water

Water is an important exposure medium and all water bodies on RMA are considered potential exposure points. The water bodies present at RMA were described in Section 1.3.2.1. and are shown in Figure 1-1. In order to ensure a conservative approach, this risk assessment focused on those water bodies that receive

the highest rate of particulate deposition and/or have physical or ecological characteristics that merit special attention. The water medium exposure points or areas selected for evaluation include: North Bog, First Creek, and Lower Derby Lake. Although Lake Ladora is physically the closest lake to the SQI, Lower Derby Lake was identified as a water medium exposure point because it would receive more particulate deposition from the SQI than any of the other lakes based on atmospheric modeling.

The North Bog merits special consideration because it is a relatively shallow water body and would receive the greatest particulate deposition of all the water bodies due to its modeled proximity to the SQI. The North Bog is in large part a mudflat with sparse to no vegetation, and it is fed by groundwater recharge and discharge from the North Boundary Containment System, rather than by stream inflow. Although populated by breeding frogs and toads, it receives less usage by waterfowl and raptors than First Creek and Lower Derby Lake.

First Creek and Lower Derby Lake were selected as exposure points because of their usage by waterfowl and raptors such as the bald eagle. Although portions of First Creek would receive more particulate matter on a daily basis than Upper Derby Lake, First Creek is a persistent intermittent stream that flows the greater part of the year. Any particulate deposited in First Creek would become diluted when the stream flowing and be transported offsite in the stream.

The equilibrium transfer of chemical contaminants between surface water and sediment represents another significant transport pathway. The sediment is ecologically important when the contaminants are dissolved hydrophobic substances that can become absorbed by organic matter in the sediment. Sediment and surface water were considered in this risk assessment to be an integrated media following EPA guidance (SEAM 1988). Bed sediments and surface water were thus considered part of a single reversible system, with bed sediments capable of acting as temporary repositories for contaminants to surface waters.

3.2.3 Vegetation

Vegetation was also considered an exposure medium in this ecological risk assessment. The exposure areas selected for consideration were those vegetation communities that were judged to have the highest potential to impact wildlife. Because prairie dogs are important in the food chain transport of contaminants to bald eagles, the vegetation communities associated with the prairie dog colonies were considered to be significant areas in terms of exposure from particulate deposition. Eagles are likely to feed anywhere within the prairie

dog communities; therefore, vegetation contamination was considered for the prairie dog colonies as a whole, rather than selecting specific receptor exposure points.

The food chain transport of contaminants to the kestrel was also considered in this risk assessment. Because the kestrel's range is limited, but not confined to the prairie dog colony, a specific exposure point was selected. For the kestrel, the area of maximum particulate deposition was selected as the exposure point in order to provide a conservative estimate of potential contaminant transport through the food chain to the kestrel.

3.3 CHEMICAL FATE AND TRANSPORT

For a chemical to pose an ecological risk to wildlife, the chemical must travel through environmental media to the exposure point and reach receptors in biologically significant concentrations. The exposure pathway must be complete or there is no exposure. The exposure pathway in this risk assessment is the release of stack emissions to the atmosphere, environmental transport of the chemicals to the exposure point, and then ingestion of the contaminated media. The term "transport" refers to the possible physical mechanisms that serve to move a chemical through the environment. "Fate" refers to the chemical and physical processes which limit (or enhance) the ability of a chemical to migrate in the environment to its ultimate location. The term "environmental fate" is broadly defined in the literature as the collective chemical phenomena which tend to attenuate a chemical and its concentration. Some of the phenomena covered by the term environmental fate include adsorption to mineral and organic particles in soil, volatilization, dispersion and dilution in ground or surface water, chemical degradation, biological degradation, and chemical speciation transformations. The physical, chemical, and environmental fate data for the selected indicator chemicals are presented in Table 2-3. Additional information on the environmental fate of many of these chemicals can be found in the cited literature.

3.3.1 Atmospheric Fate and Transport

The predominant mechanisms that affect atmospheric fate and transport of substances released to the air are advection, dispersion, and chemical degradation. Ambient chemical concentrations at a specified distance from the SQI can be determined as a direct function of a the emission rate. Ambient chemical concentrations at the identified exposure points were estimated using the Industrial Source Complex (ISC) air dispersion computer model as recommended in EPA risk assessment guidance. Similarly, the rate of

chemical deposition onto soil, surface water, and vegetation at the exposure points was determined by the ISC transport model.

3.3.2 Air Deposition Modeling

The ISC model is a steady-state Gaussian plume model designed to assess ground-level, pollutant concentration from a variety of sources associated with an industrial source complex. The major features and capabilities of the ISC model are:

- Polar or Cartesian coordinate system

- Plume rise due to momentum and buoyancy as a function of downwind distance for stack emissions (Briggs 1971 and 1975)

- Procedures suggested by Huber and Snyder (1976) and Huber (1977) for evaluating building wake effects

- Procedures suggested by Briggs (1973) for evaluating stack-tip downwash

- Separation of multiple point sources

- Consideration of the effects of gravitational settling and dry deposition on ambient particulate concentrations

- Simulation of point, line, volume, and area sources

- Calculation of dry deposition

- Variation of wind speed and height using the wind-profile exponent law

- Concentration estimates for averaging periods ranging from 1 hour to 1 year

- Consideration of time-dependent exponential decay of pollutants

Special discrete receptors in either polar or Cartesian coordinates may be specified to correspond to monitoring sites, probable points of maximum impact, and special points of interest. ISC also has a long-term version, ISCLT, which is typically used for averaging periods of 1 year or longer. ISCLT is a sector-averaging model that treats variations in wind direction across a $22.5°$ sector by assuming uniform horizontal dispersion. Thus, a statistical summary of annual meteorology classified by wind direction spaced at $22.5°$ intervals by wind speed class and by stability class is input. ISCLT uses hourly sequential meteorological data, yielding concentration estimates that are more sensitive to wind direction variations.

Total annual deposition from the SQI was calculated with ISCLT. A "chi/q" (concentration/emission rate) approach was followed with emissions from the stack source assumed to be 1 gram (g) per second for 1 year (yr) (i.e., 31,536,000 g/yr) with resultant deposition predictions expressed as grams per square meter (g/m^2). Particle size distribution and corresponding settling velocities were input according to generic values found in the EPA publication AP-42 (EPA 1985) and from acid deposition research (Galloway et al. 1980).

Annual average chi/q values at exposure points (receptors) were modeled using a grid of sufficient density to indicate the distribution of chi/q deposition as a function of distance from the SQI stack source. The emission rate of each constituent was multiplied by the modeled annual chi/q deposition to obtain the annual constituent deposition at a particular exposure point.

The following assumptions were used in the deposition modeling process:

- Air emissions originate from one stack source located 50 to 100 yards south of the Basin F Liquid Storage Tanks in Section 26.

- One year of hourly meteorological data from Stapleton International Airport for the calendar year 1988 was assumed to be representative of potential dispersion conditions at the Basin F site based on proximity and similarities in both topography and climatology. Statistical summaries of wind speed, wind direction, and stability class were computed with mixing height and temperature assignments consistent with the recommendations described in the ISC user's manual (EPA 1987). Mixing heights were input according to seasonal averages during the morning and afternoon. Wind speed for any given hour was not allowed to be less than one meter per second as per EPA Modeling Guidelines.

- For worst-case (maximum) estimates of annual deposition, all particulates were assumed to be retained on the ground, vegetative, or water surface once they are deposited.

The chemical concentrations in soil, biomass, and surface water were calculated using this maximum deposition rate at a particular exposure point.

A set of annual deposition contours for particulate was generated from the grid of modeled exposure points consisting of 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.11, 0.36, 0.61, 0.86 and 1.22 $g/m^2/yr$ (Figure 3-1). By examining modeled annual particulate deposition at the grid receptors, this range of contours was deemed to be representative of the deposition distribution. Corresponding values of these contours for each of the semi-volatile and metal compounds considered in this risk assessment were obtained by multiplying the particulate deposition contour values by the ratio of the compound and particulate emission rate. In addition, resultant soil, biomass, and surface water concentrations from the modeled deposition were estimated by using specific assumptions to define a mass within which the deposited compound in particulate form would uniformly mix. An estimate of the maximum soil, biomass, and surface water concentration for each chemical was calculated by using the corresponding modeled maximum deposition for particulate, 1.22 $g/m^2/yr$. Procedures and assumptions used to estimate soil, surface water, and biomass (vegetation) concentrations using the modeled particulate deposition are described in Sections 3.4.2, 3.4.3, and 3.4.4, respectively. Resultant soil, biomass, and surface water concentrations corresponding to particulate deposition contours of 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.11, 0.36, 0.61, 0.86, and 1.22 $g/m^2/yr$ for each compound are summarized in the Appendix.

The approximate area of maximum deposition noted in Section 3.2.1 was estimated based on the modeled point of maximum exposure, the receptor grid, and the distance to the first isopleth (1.2 $g/m^2/yr$). For the purposes of the exposure assessment, it was assumed that the maximum point of exposure was as large as 150 ft by 150 ft, a conservative assumption. The point of maximum impact based on the model would be approximately ¼ mile north/northeast of the ISC.

3.4 EXPOSURE POINT CONCENTRATIONS

Air modeling results were used to calculate the compound deposition rates for total particulate and individual chemicals at each exposure point or area. The deposition rates are plotted as concentration isopleths in $g/m^2/yr$ (Figure 3-1). The emission rates and compound deposition rates for particulates and the indicator chemicals are presented in the Appendix.
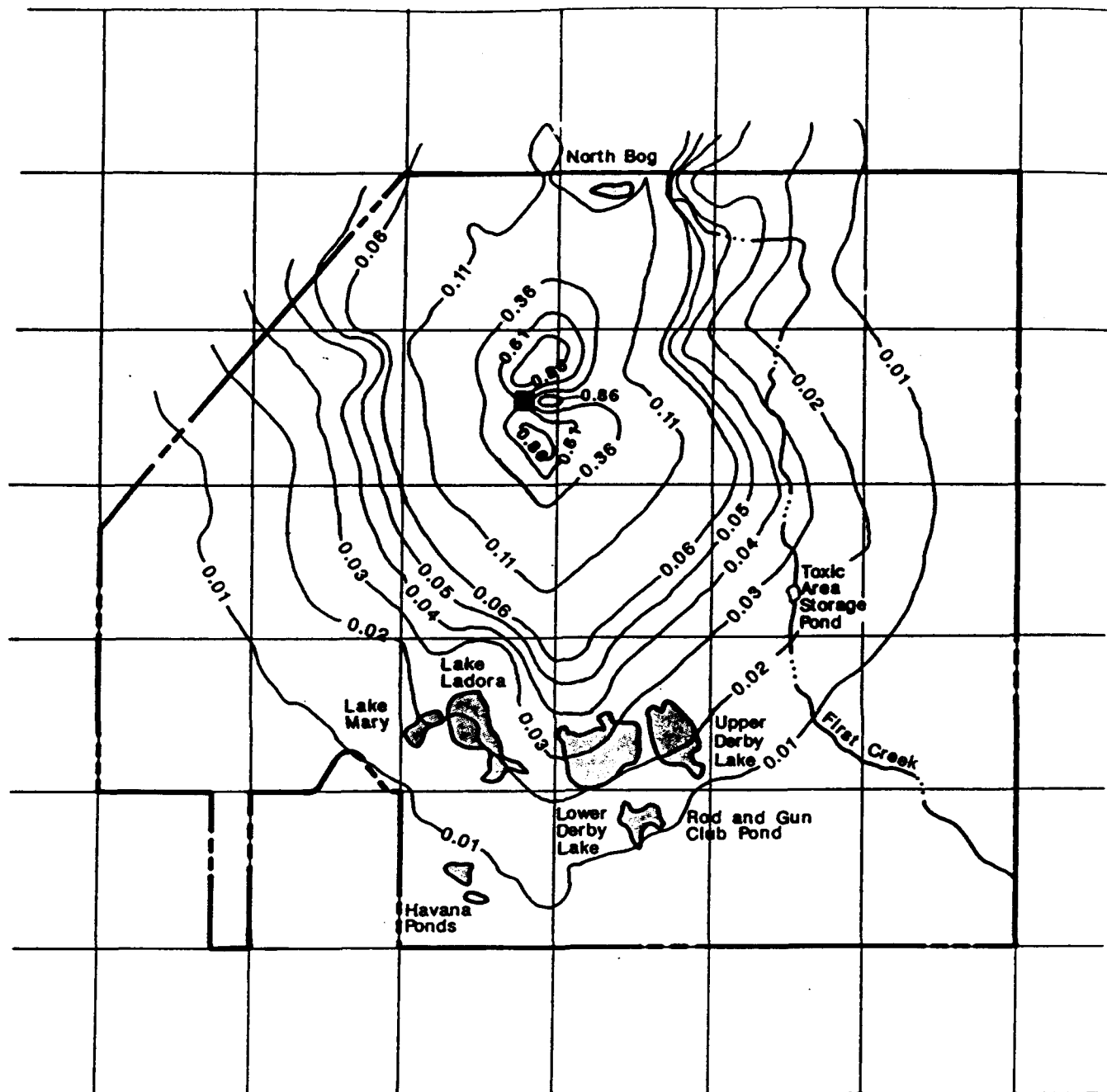
ISOPLETH CONCENTRATIONS ARE IN g/m²/year
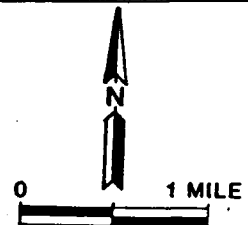
LEGEND

■ PROPOSED SQI

0   1 MILE

Job No. : 2001-375	PARTICULATE DEPOSITION ISOPLETHS
Prepared by : J.J.A.	
Date : 4/20/90	Figure 3-1

Once the deposition rates were known, the resultant concentrations for the individual chemicals on soil, surface water and vegetation media for each exposure area were calculated. Figures 3-2 and 3-3 show the selected exposure areas (prairie dog colonies and water bodies) in relation to the concentration isopleths. In calculating the resultant concentrations for each media, a number of assumptions were made. These assumptions and the methods for calculating the resultant chemical concentrations in the soil, water, and vegetation media are presented in the following sections.

3.4.1 Soil Concentrations

It was assumed for this risk assessment that chemicals are deposited onto soil, and that soil is subsequently ingested by the exposed wildlife. Chemicals deposited on the soil are assumed to mix with the top one-half to one-quarter inch of disturbed soil. For this risk assessment, it is conservatively assumed that mixing occurs to a depth of 0.25 inches (0.635 cm). Reported surface soil density ranges from 1,040 to 1,602 kilograms per cubic meter (kg/m^3). The weight of the mixed soil in 1 square meter is 6.6 kg (6.35E-03 m x $1m^2$ x 1040 kg/m^3) using the more conservative density value. If it were assumed that no mixing took place, the particulate would become airborne through surface wind erosion. Actual surface soil concentrations may be lower than the values calculated since the deposited particulate will likely mix within a soil layer that is susceptible to wind erosion.

Chemical deposition will occur throughout the expected lifetime of the SQI (1.5 years). The average chemical concentrations in RMA soil due to SQI emissions were calculated by the following formula:

$$\text{Chemical Concentration in Soil} = C_{soil} \text{ (mg/kg)} = \frac{\text{RPD (g/m}^2\text{/yr) x DD (yr) x UCF}}{\text{Weight of mixing soil per unit area (kg/m}^2\text{)}}$$

where:

$$\text{RPD} = \text{Rate of Particulate Deposition (g/m}^2\text{/yr)} = \text{Emission Rate x Chi/Q}$$

and:

Emission rate = chemical emission rate from the SQI incinerator stack (g/sec)

$$\text{Chi/Q} = \text{Air Deposition Modeling Factor} = 2.989 \ \frac{g/m^2/yr}{g/sec}$$

Woodward-Clyde Consultants

ISOPLETH CONCENTRATIONS ARE IN g/m²/year

LEGEND

PRAIRIE DOG COLONY RANGE

PROPOSED SQI

EAGLE FEED OBSERVATION (87-88 Winter)

EAGLE FEED OBSERVATION (86-87 Winter)

N

0   1 MILE
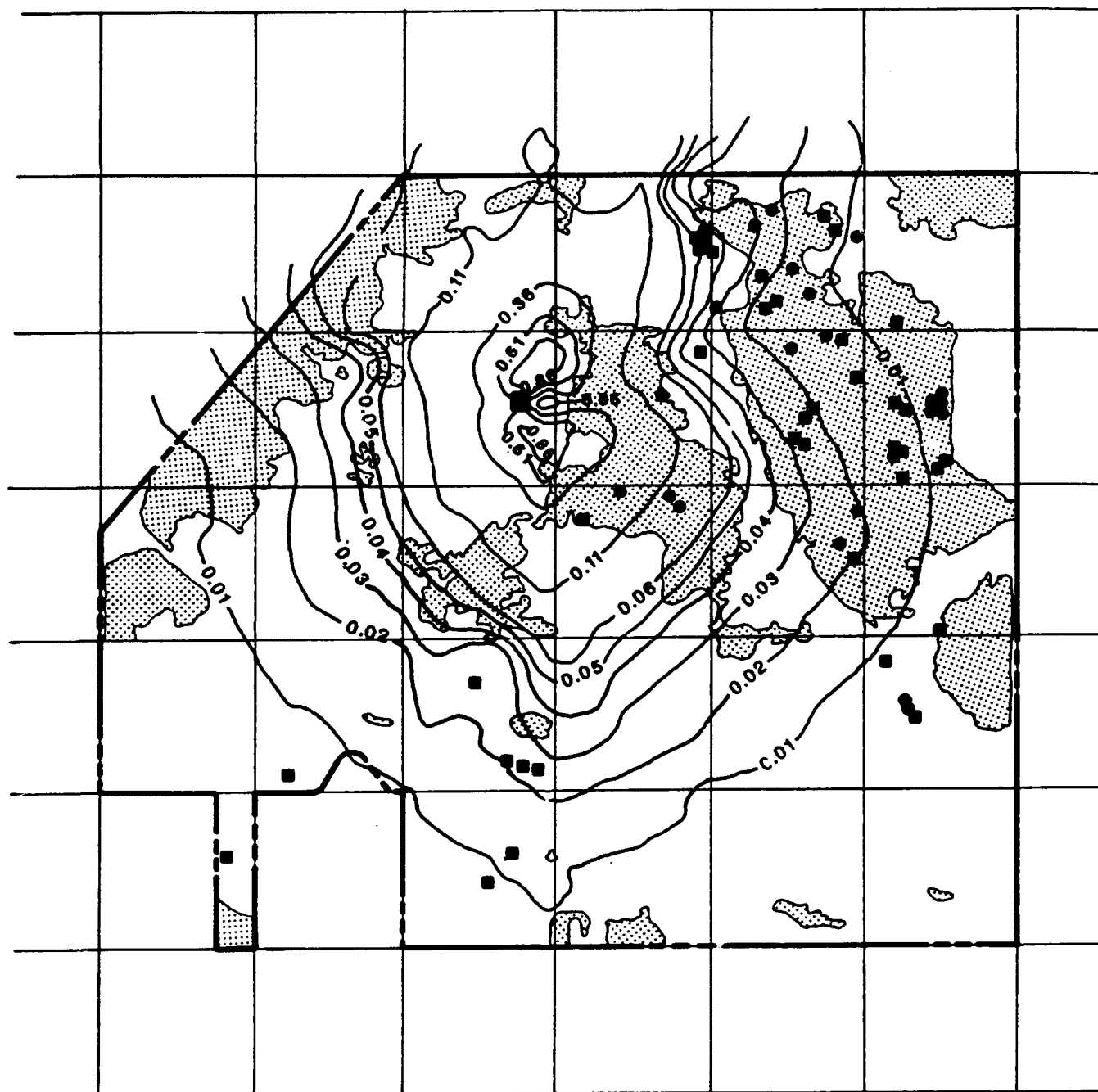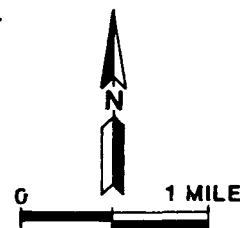
Job No. : 2001-375	PRAIRIE DOG COLONIES, BALD EAGLE
	FEEDING LOCATIONS, AND CHEMICAL
Prepared by : J.J.A.	DEPOSITION ISOPLETHS
SOURCE: WCC, 1990	
Date : 4/20/90	Figure 3-2
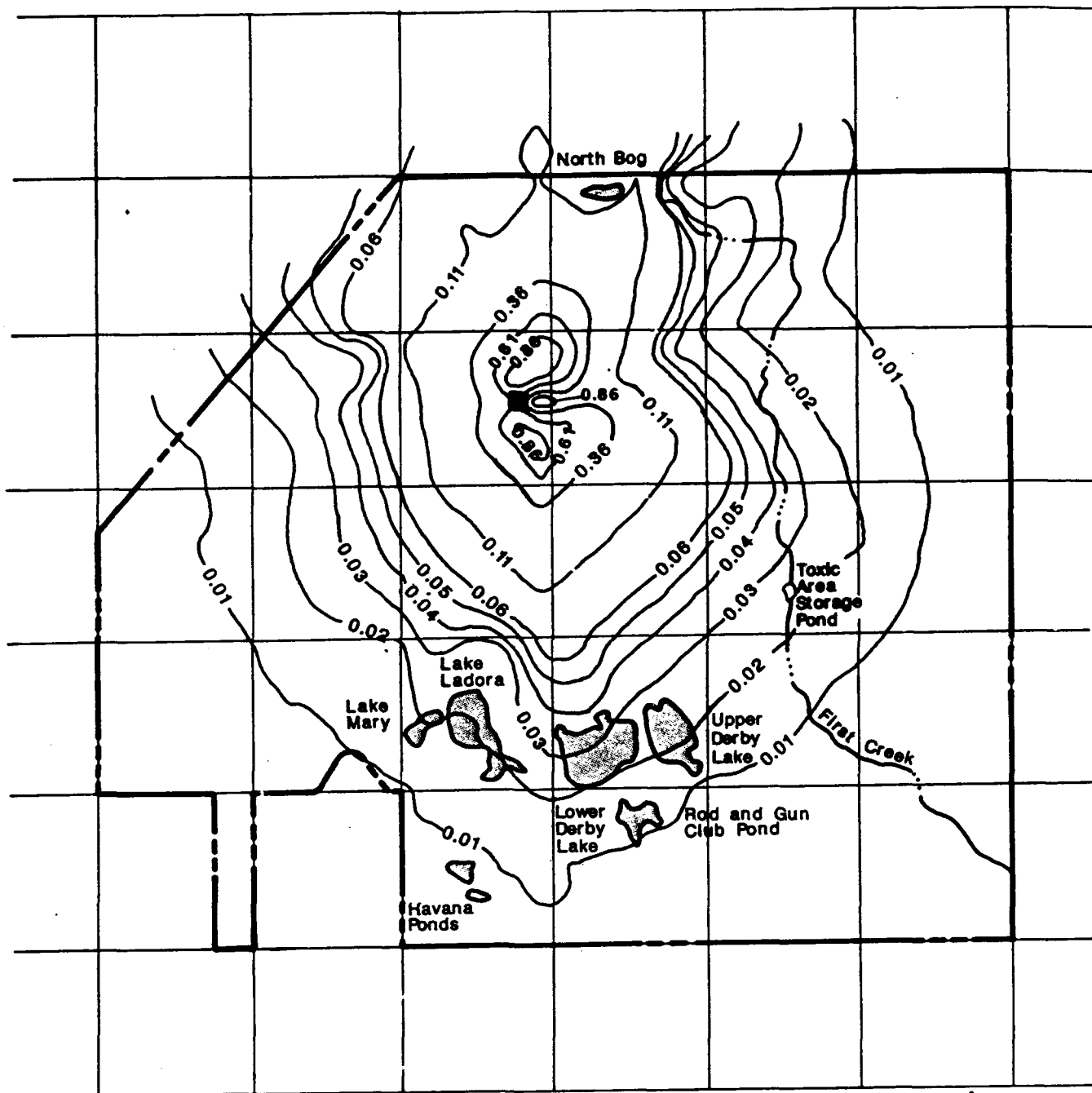
ISOPLETH CONCENTRATIONS ARE IN g/m²/year

LEGEND

■ PROPOSED SQI

N

0   1 MILE
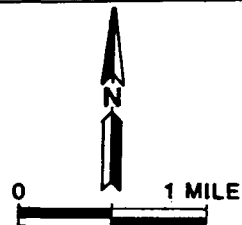
Job No. : 2001-375	RMA WATER BODIES AND CHEMICAL
Prepared by : J.J.A.	DEPOSITION ISOPLETHS
Date : 4/20/90	Figure 3-3

UCF = Unit Conversion Factor = 1.0E+03 mg/g

DD = Deposition Duration = 1.5 yrs (time SQI is in operation)

Weight of mixing soil = calculated as 6.6 kg/m^2 assuming a mixing depth of 0.25 inches.

The prairie dog colonies were selected as the most important soil exposure points, primarily because of their importance in the eagle food web and because these mammals stay in the same area thus receiving the maximum potential for chemical exposure. The total particulate deposition concentrations (g/m^2/yr) in relation to the prairie dog colonies are shown in Figure 3-2. The two exposure points considered in this risk assessment were the point of maximum particulate deposition impact for kestrel exposure (1.22 g/m^2) and the nearest prairie dog colonies for eagles (0.11 g/m^2). The concentrations for each of the indicator chemicals in soil at the selected exposure points are presented in the Appendix.

3.4.2 Surface Water Concentrations

For the surface water media, it was assumed that chemicals are deposited onto the water bodies at RMA, and that the chemicals completely dissolve in the water. This is a conservative assumption since the metals will be present as metal oxides which have low water solubilities and the carbon matrix of the particulate will also lower metal solubilities. In order to ensure that water concentrations were conservative and that the risk would not be underestimated, the water volume used to calculate concentrations for North Bog, First Creek, and Lower Derby Lake was limited to the top 12 inches (30.48 centimeters) of the water body. The resultant surface water chemical concentration is calculated by the following equation:

Chemical Concentration in Surface Water [C_{sw}(mg/l)] = $\dfrac{\text{RPD (g/m}^2\text{/yr) x DD (yr) x UCF}}{\text{Volume of water per sq. meter of 1 ft depth (l/m}^2\text{)}}$

where:

RPD = Rate of Particulate Deposition (g/m^2/yr) = Emission Rate x Chi/Q

Emission rate = chemical emission rate from the SQI incinerator stack (g/sec)

Chi/Q = Air Deposition Modeling Factor = 2.989 $\dfrac{\text{g/m}^2\text{/yr}}{\text{g/sec}}$

UCF = Unit Conversion Factor = 1.0E+03 mg/g

DD = Deposition Duration = 1.5 yrs

Volume of water = 12 inches x 2.54 cm/inch x 10,000 cm²/m² x 1 liter/1000 cm³

= 3.05E+02 liters/m²

Three exposure points (North Bog, First Creek, and Lower Derby Lake) were selected in this risk assessment. The total particulate deposition (g/m²/yr) at each of these exposure points is shown in Figure 3-3. Surface water concentrations for each chemical at each of the exposure point isopleths (0.06, 0.05, and 0.03 g/m² respectively) are presented in Appendix A.

3.4.3 Vegetation Concentrations

The particulate matter concentrations in vegetation biomass in the impact areas are calculated from the total particulate deposition rate as follows:

Chemical Concentration in Biomass [C_{bio} (mg/kg)] =

$$\frac{\text{RPD (g/m2/yr) x \% plant cover x \% removal by rain x DD x UCF}}{\text{Biomass Fresh Weight (kg/m}^2)}$$

    where:

RPD = Rate of Particulate Deposition (g/m²/yr) = Emission Rate x Chi/Q

Emission rate = chemical emission rate from the SQI incinerator stack (g/sec)

Chi/Q = Air Deposition Modeling Factor = 2.989 $\frac{g/m^2/yr}{g/sec}$

Unit Conversion Factor (UCF) = 1.0E+03 mg/g

DD = Deposition Duration = 1.5 yrs

Biomass fresh weight = 0.2 kg/m² (200 g/m²); based on a conservatively assumed dry weight of 100 g/m² and a dry:wet weight ratio of 50 percent

percent plant cover = 50 percent

percent removal of particulates from plant surfaces by rain (wind and snow) = 50 percent

Reported dry weight biomass values on RMA range from 96.7 g/m² for the native perennial grass community to 140.3 g ²² for the cheatgrass/weedy forb community (MKE, 1989). The latter community is the most extensive on RMA, and one in which the prairie dog is typically found. These values are representative of the average Soil Conservation Service (SCS) production values for the loamy plains range site: 900 to 1000 lbs/acre or 100 to 112 g/m² (SCS, 1974). For this calculation, 100 g/m² was used to provide a conservative estimate of chemical concentrations in dry weight biomass.

The above production values, however, are for oven dry weight. An average of approximately 20 percent of total fresh weight of many plants is herbaceous dry matter (Salisbury and Ross 1969). In the plains grass community, this percentage can be expected to vary depending on the time of year, from approximately 20 to 25 percent in the spring, to 50 percent in the fall, and from 70 to 90 percent in the winter. A biomass dry:wet weight ratio of 0.50 was assumed to be a reasonable conservative estimate that represents the annual average and allows the calculation of chemical concentrations in fresh biomass.

In the plains grass community, plant cover is typically less than 100 percent. Cover values for the major vegetation communities on RMA range from 28.5 percent for the crested wheatgrass community to 34.5 percent for the native grass community to 45.8 percent for the cheatgrass/weedy forb community (ESE 1989). A value of 50 percent was selected as a conservative estimate for the amount of particulate that is deposited on plants, as opposed to soil, litter, or rock. Of the particulate that is deposited on live vegetation, half is assumed to be washed off by rain or snow or blown off by wind. A value of 50 percent was therefore selected as a conservative estimate for the amount of particulate that remains on plants that would be potentially ingested by wildlife. A deposition duration of 1.5 yrs was also used as a conservative estimate, even though live vegetation is not present throughout the year.

For this risk assessment, it was assumed that eagles are likely to feed anywhere within the prairie dog colonies; therefore, a weighted average chemical deposition was used to estimate the vegetation chemical concentrations. This value was equivalent to chemical deposition concentrations which would occur within

the 0.04 isopleth. This calculation is discussed in Section 4.2.3.2. The weighted average concentration provides a conservative estimate of exposure since most eagle feeding locations are east of First Creek and outside the 0.03 isopleth (Figure 3-2).

3.5 CHEMICAL OR MEDIA INTAKE ROUTES

Media intake routes are the final connection between chemical release and the wildlife. Several of the potential human media intake routes for chemical emissions from the SQI are also potential intake routes to the flora and fauna at RMA and particularly the bald eagle. The potential routes include inhalation of volatilized chemicals and particulate in the air, inhalation of dust from contaminated soil, dermal exposure to contaminated surface waters and soils, and ingestion of contaminated soils, surface water, and vegetation.

Ingestion was considered the most important route in this risk assessment. The ingestion route for wildlife has two components: terrestrial and aquatic. Both of these components are described in the following sections. The inhalation and dermal intake routes were not evaluated in this risk assessment as these routes were judged not to be significant chemical intake routes that would produce adverse effects. Additional rationale for not including the inhalation and dermal intake routes are presented in Section 4.3, Risk Characterization.

3.5.1 Ingestion

Intake of SQI chemicals may occur from ingestion of soil, water, and vegetation. Because of the low chemical concentrations involved, it is assumed in this risk assessment that bioconcentration or bioaccumulation has the greatest potential to impact RMA wildlife. Because several indicator chemicals, such as the pesticides, are known to bioaccumulate and bioconcentrate, their potential exposure routes through food web pathways were examined in detail.

The site-specific BRI terrestrial (soil-biota) and aquatic (sediment-water-biota) food web or ingestion pathways were used to evaluate ecological risks at RMA. The BRI pathways approach involves a multiple food chain pathway analysis to address the potential for adverse effects at various trophic levels and the potential for contaminants to bioaccumulate within food webs. The pathways approach incorporates

exposure estimates by various organisms to contaminants present in the environment. This approach takes into consideration the potential for the following key factors:

- Bioconcentration (concentration from direct exposure to water in an aquatic medium);

- Bioaccumulation (concentration from water and from diet); and

- Biomagnification (systematic increase in concentration as contaminants move through food chains to higher trophic levels).

By using this approach, "no effects" soil and water concentrations or criteria were derived in the BRI for various contaminants. These criteria take into account direct health effects without bioaccumulation as well as contaminant levels which can adversely affect biota at lower trophic levels. The "no effects" levels can be used as site-specific criteria against which SQI emissions chemical concentrations in soil, water, and vegetation can be compared.

Bald eagles and raptors, such as the kestrel, are conspicuous components of the terrestrial biota on RMA as well as species of special interest. As predators at the top of the food chain, these species are most susceptible to the effects of contaminant bioaccumulation. Bald eagles at RMA derive a major portion of their food supply from prairie dogs and lagomorphs; fish and waterfowl contribute to a lesser extent. Bioconcentration and bioaccumulation through the aquatic and terrestrial ingestion routes are therefore potentially significant indirect exposure routes.

Two separate food webs (bald eagle and kestrel) were developed in the BRI for use in the exposure pathway analysis for the major BRI contaminants of concern to RMA wildlife. The bald eagle food web was composed of both aquatic and terrestrial food chains, whereas the kestrel food web was composed of strictly terrestrial food chains. The eagle food web was applied first in the pathways model. If biomagnification was insignificant (factors less than one) in the single terrestrial eagle food chain, then results were assumed to be similar for the terrestrial kestrel food web, which includes seven food chains. Dieldrin was the only major contaminant in the BRI where eagle biomagnification was significant and thus the kestrel food web was considered.

3.5.2 The Terrestrial Pathway (Soil/Vegetation)

Terrestrial pathway bioaccumulation is estimated by comparing chemical concentrations in soil and diet to chemical concentrations in tissue levels at successively higher trophic levels. By comparing chemical concentrations in biota to those in the diet throughout the food chain pathway, the increase in concentration or biomagnification factor (BMF) can be determined.

The principal terrestrial pathway for the bald eagle at RMA is:

    Soil --> Terrestrial Plants --> Small Mammals --> Bald Eagle

By considering the BRI-derived bioaccumulation rate for each trophic level, the total BMF in the terrestrial ecosystem can be calculated. The following example is given to calculate the BMF for arsenic:

$$0.02 \quad x \quad 3.5 \quad x \quad 0.08 \quad = \quad 0.0056$$
    Soil --> Terrestrial Plants --> Small Mammals --> Bald Eagle

The total magnification or the amount of arsenic accumulated by the eagle in this terrestrial food pathway is therefore 5.6E-03 times the amount found in soil. Usually, the terrestrial pathway would only comprise 10 percent of the eagle diet so that the total BMF would equal 5.6E-04. On RMA, however, the terrestrial pathway can account for 90 percent of the eagle's diet, so the total BMF would equal 5.0E-03.

The maximum allowable chemical level in soil at RMA was established by relating the total BMF based on the pathways analysis to the Maximum Acceptable Tissue Concentration (MATC) published for similar avian species (ESE 1989). The MATC is based on the lowest observed effects level (LOEL) obtained from the scientific literature for a species similar to the target organism. In using the MATC, it is assumed that criteria developed for the protection of the target organism (bald eagle) will protect all other wildlife species. The "no effects" soil concentration protective of key organisms at the top of the food web pathway is estimated by dividing avian species MATC by the eagle BMF.

For this risk assessment, the final chemical concentration in eagle tissue was calculated from the BMF value and the modeled soil chemical concentration. The final tissue concentration can then compared to the MATC value for a particular chemical. This approach was used to evaluate wildlife risks.

When the BMF was greater than one in the eagle pathway, indicating that the chemical is concentrating in the food chain, a separate pathways analysis food web was used for the kestrel based on seven separate terrestrial food transfer pathways. Each of the seven pathways was evaluated for the kestrel in order to estimate a "no effects" soil concentration for the contaminant of concern. Dieldrin was the contaminant of concern in the BRI report which required use of the seven terrestrial food transfer pathways. The food pathways for the kestrel are as follows:

1. Soil -> Plants -> Insects -> Kestrels
2. Soil -> Plants -> Birds -> Kestrels
3. Soil -> Earthworms -> Birds -> Kestrels
4. Soil -> Plants -> Insects -> Birds -> Kestrels
5. Soil -> Plants -> Insects -> Reptiles -> Kestrels
6. Soil -> Plants -> Insects -> Mammals -> Kestrels
7. Soil -> Plants -> Mammals -> Kestrels

The "no effects" level for soil from the BRI pathway analysis was based on sublethal effects levels obtained from published literature and assumes that if the top trophic level target species, the kestrel, is not affected, other species, such as the bald eagle, will be protected. To perform the pathways analysis, information on health effects levels, food habits for species at each trophic level, and BMF values for species at each trophic level were used. The analysis was performed by using BMFs for each trophic level in a food chain, and then weighting the importance of each food chain in a food web by utilizing food habits data. The end result is a total estimated BMF for the target species, the kestrel, that can then be used to estimate a safe soil level or criteria considered to be protective of all other terrestrial wildlife.

3.5.3 The Aquatic Pathway (Water/Sediments)

The aquatic pathway presents the greatest potential for receptor population exposure to chemicals that bioconcentrate or bioaccumulate. The aquatic food pathway is evaluated differently than the terrestrial food pathways. In terrestrial ecosystems, the bulk of contaminant accumulation is a function of uptake from diet. In aquatic pathways, contaminant accumulation is a function of uptake from water and sediment, by diet and continual exposure. Therefore, bioconcentration is more significant in the aquatic food pathway.

Aquatic organisms are considered to be important links in the bald eagle food web because they are near the bottom of the food web and are constantly exposed to the contaminants in their environment via surface

adsorption, absorption, and uptake across respiratory membranes. Most chemical accumulation in aquatic ecosystems is derived from water and sediment. Accumulation due to consumption of contaminated food is not as important. Concentration factors from the abiotic environment through the aquatic food web are typically large.

The BRI aquatic pathways analysis is based on the bald eagle sink food subweb (portion of the comprehensive ecosystem food web leading to a target species) and includes all major food chains leading to the bald eagle. The bald eagle was selected as the target species because of its endangered species status and because it represents the highest trophic level potentially affected by contaminant bioaccumulation through aquatic food chains.

The Thomann (1981) bioaccumulation model of food chain transfer in aquatic ecosystems was used in the BRI aquatic pathways analysis to estimate bioaccumulation factors. Because the same organisms/groups appear in more than one food chain throughout the web, percentage contributions for each organism were estimated from published literature. The calculated biomagnification is based on bioconcentration and bioaccumulation, the processes that increase tissue chemical concentrations as the chemical is transferred up food chains. The BRI identified the following seven aquatic food pathways ultimately terminating with the bald eagle (ESE, 1989):

1. Water -> Snails -> Mallard -> Eagle
2. Water -> Chironomid -> Mallard -> Eagle
3. Water -> Invertebrates -> Mallard -> Eagle
4. Water -> Aquatic plants -> Mallard -> Eagle
5. Water -> Plankton -> Bluegill -> Pike -> Eagle
6. Water -> Invertebrates -> Bluegill -> Pike -> Eagle
7. Water -> Chironomid -> Bluegill -> Pike -> Eagle

The number of pathways considered in the BRI varied with each contaminant depending on the quality and quantity of data available for the analysis. All seven pathways were used for dieldrin; five pathways were used for mercury and four aquatic pathways were considered for endrin and arsenic. All species at a particular trophic level were considered to be represented by the key species at that level; e.g., mallards were selected to represent all waterfowl.

The maximum allowable chemical level in water at RMA was established in a similar manner to soil by relating the total pathways BMF to published MATC values. Dividing the published MATC for an avian species by the calculated eagle, BMF gives a water concentration at which "no effects" are likely to occur to key organisms at the top of the food web pathway.

Exposure point concentrations were compared to site-specific soil and water criteria developed for flora and fauna at RMA. The following sections describe how these criteria were used to evaluate the risk of chemical emissions from the SQI to RMA wildlife.

4.1 DEVELOPMENT OF ECOLOGICAL RISK CRITERIA

Criteria that are usable and applicable for the evaluation of ecological risk are generally limited. EPA Ambient Water Quality Criteria (AWQC) and MATC are the most readily available criteria. Site-specific acceptable criteria protective of aquatic and terrestrial wildlife were developed as a part of the BRI study. Criteria protective of wildlife and plants were developed for most of the BRI contaminants of concern based on the pathways analysis approach as described in the previous section. Detailed pathways analyses were performed for the major contaminants of concern (aldrin/dieldrin, arsenic, endrin/isodrin, and mercury), to determine water, soil, and sediment criteria that would be protective of site-specific biota.

BRI ecological risk criteria for soil and water were developed by tracing the biomagnification of contaminant residues from organisms at the top of the food web, back through intermediate trophic levels to the abiotic environment. The "no effects" levels for soil and water were derived from the pathway analyses and are based on sublethal effects and assume that when the highest trophic level organism (bald eagle or kestrel) is protected, all other species are protected. Likewise, criteria developed from the health effects data and water consumption rates for small mammals were assumed to be protective of large mammals as well.

4.1.1 Soil Criteria

Two criteria were available for the evaluation of soil concentrations resulting from SQI emissions. The first criterion, Certified Reporting Limits (CRLs), was used in the Remedial Investigation Contamination Assessment Reports (CARs) and Study Area Reports (SARs) to determine chemical concentrations of environmental significance in RMA soils. The second criterion was the "no effects" soil chemical levels that were developed in the BRI.

The CRL criteria are not based on toxicity or health effects, but represent the lower limit of detection for each chemical in RMA soils. The CRL is defined as the lowest concentration of analyte in a sample being analyzed that can be reported within a ninety percent confidence interval, using valid precision and accuracy criteria (EBASCO et al. 1989).

Organic chemicals are treated differently from metals with respect to CRLs. For organic chemicals, any detectable concentration is considered to be the result of disposal practices, agricultural practices, or dispersion from contaminated areas. Concentrations of organic chemicals below the CRL are not considered to be environmentally significant (EBASCO 1989). Soil CRLs for the organic compounds evaluated in this risk assessment are presented in Table 4-1.

For metals, indicator ranges are used as the criteria by which to evaluate contamination. The lower limit of the indicator range for metals is the CRL. The upper limit of the indicator range is considered to be consistent with natural conditions and reflective of concentrations expected to occur naturally in RMA alluvial soil. Values above the indicator range are considered to be indicative of contamination. The indicator ranges for metals, their range of concentrations in western soils, and their concentration range in bulk soils from nonsource (uncontaminated) RMA areas are presented in Table 4-2.

The BRI criteria were developed to identify soil concentrations that are protective of RMA wildlife populations. These criteria were reported in the BRI to the extent that appropriate data were available. The BRI soil criteria were based on No Observed Effects Levels (NOELs) and MATC values as previously described in Section 3.5.2. BRI soil criteria for bioaccumulative contaminants, where the pathways approach was not used (e.g., DDT/DDE), were developed by selecting the lowest of two values: (1) soil criteria derived from direct toxicity or (2) criteria derived from Final Residue Values for the water ingestion route. The latter criteria were adapted for a terrestrial system by using an ecological magnification factor in place of a bioconcentration factor (ESE 1989). The BRI criteria for soils are presented in Table 4-1.

The direct ingestion of soil biota was considered in the development of the BRI Criteria to the extent that data were available. Data on toxic effects to biota through direct ingestion, however, are generally limited. The method used to estimate the soil BRI criteria relied instead on calculating overall residue magnification. Although soil ingestion rates were not applied in the soil criteria formulation, soil ingestion rates were compared to soil criteria for each contaminant to ensure that criteria were protective of both food and soil ingestion exposure.

TABLE 4-1
BRI Biota and CRL Soils Criteria[1]

	BRI[2] (ppm)	CRL[3] (ppm)
Aldrin	1.0E - 01	**1.8E - 03**
B2EHP	--	--
DNBP	--	--
CPMSO	**9.7E - 01**	2.3E + 00
CPMSO2	**9.7E - 01**	2.4E + 00
Dieldrin	1.0E - 01	1.2E - 03
DDT/DDE	4.0E + 00	1.0E - 03
DIMP	1.58E + 01	5.0E - 02
DMMP	--	5.0E - 02
Dithiane	--	6.0E - 01
Endrin	9.2E + 00	1.0E - 03
Isodrin	9.2E + 00	1.1E - 03
Malathion	**2.5E - 02**	2.5E - 01
Parathion	--	2.5E - 01
dioxins/furans	--	--
METALS		
Arsenic	5.2E + 01	2.5E + 00
Antimony	--	--
Barium	--	--
Beryllium	--	--
Cadmium	1.3E + 01	5.1E - 01
Chromium	--	5.2E + 00
Copper	1.0E + 02	4.7E + 00
Lead	--	8.4E + 00
Nickel	--	--
Silver	--	--
Mercury	1.1E + 00	5.0E - 02
Thallium	--	--

[1]   Values in bold are most conservative criteria

[2]   ESE, 1989

[3]   Lowest CRL value for metals reported for any lab (MRI, DATACHEM, CAL, ESE); Lowest Phase II
Certified Reporting Limit of organic compounds in soils for three laboratories,
ESE, Datachem, CAL. (EBASCO, 1989a)

--   No criteria available

TABLE 4-2
Soils Criteria for Metals

Metal Concentration (ug/g or ppm)

	Indicator Range[1]	western soils[2]	RMA nonsource soils[3]	SQI soil deposition[4]
Arsenic	2.5 - 10	2.8 - 10.9	2.5 - 50	0.059
Cadmium	0.51 - 2.0	0.1 - 0.5	0.66 - 7.8	0.064
Chromium	5.2 - 40	19 - 90	6.4 - 55	0.0058
Copper	4.7 - 35	10 - 43	5 - 46	2.11
Lead	8.4 - 40	9 - 31	10 - 120	0.20
Mercury	0.05 - 0.10	0.02 - 0.11	0.05 - 1.2	0.037

[1] Indicator range: lowest CRL value reported for any lab (MRI, DATACHEM, CAL, ESE) to highest level expected to occur naturally in RMA alluvial soils (EBASCO et al., 1989)

[2] Range in concentrations reported for western soils (Shacklette and Boerngen, 1984)

[3] Range in concentrations reported for bulk soils from nonsource areas on RMA (ESE, 1987)

[4] Maximum Soil Concentration from SQI particulate deposition over 1.5 years at the area of maximum impact

For this ecological risk assessment, the more conservative of the two criteria, BRI or CRL, were selected for comparison with the resultant SQI deposition concentrations. The lowest criteria values are in bold print in Table 4-1. Even though the BRI and CRL criteria are based on different principles, both criteria were used for comparison to SQI resultant soil concentrations. Some SQI chemicals did not have BRI or CRL criteria. These chemicals included the phthalates, dioxins, antimony, barium, beryllium, nickel, silver, and thallium. It was assumed for these chemicals that the aquatic criteria would be more conservative than terrestrial criteria. Therefore, chemical concentrations were considered to be of no risk to wildlife when concentrations of these chemicals in water did not exceed EPA AWQC that are protective of wildlife.

4.1.2 Aquatic Criteria

The water quality criteria used in this ecological risk assessment were primarily based on EPA AWQC for the Protection of Freshwater Aquatic Organisms and Their Uses (EPA 1986b). Two additional criteria used to evaluate risk were the BRI (ESE, 1989) and CRL values (EBASCO et al. 1989a, 1989b). Table 4-3 lists the three criteria (BRI, AWQC, and CRL). In order to provide a conservative estimate of risk, the lowest of the three criteria was used to compare resultant deposition water concentrations from the SQI.

It should be noted that CRL criteria are based on analytical detection limits rather than health-related or toxic effects in aquatic species. The reported CRL values are the lowest CRL value used in the Task 4 and Task 44 water sampling programs (EBASCO et al. 1989b). Values above the CRL for water were considered to be indicative of contamination, but not necessarily indicative of ecological risk. In some cases, the CRL values were lower than the AWQC or BRI criteria; e.g., CPMSO2, CPMSO, DIMP, DMMP, dithiane, arsenic, and chromium (Table 4-3). BRI and AWQC criteria for chemicals which bioaccumulate, such as mercury and the organopesticides, are generally lower than the CRL.

The EPA chronic AWQC are generally the most conservative health-based criteria available. In the case of the dioxins and furans, the EPA criteria are the only criteria available. The AWQC for dioxins, however, are based on the latest draft guidelines, as the EPA has not yet developed final criteria due to insufficient data. Human health criteria were used for barium, as AWQC are not available. AWQC are also not available for CPMSO, CPMSO2, DMMP, dithiane, and isodrin. Finally, it should be noted that in the case of cadmium, copper, lead, nickel, and silver, the AWQC criteria are hardness dependent; therefore, the standard becomes more conservative as the hardness of the water decreases below the standard value of 100 mg/L as $CaCO^3$. Average hardness values were reported for Lower Derby Lake, Lake Ladora, and Lake Mary at 141, 179, and 116 mg/L, respectively, over a 4-month sampling period in 1987 (EBASCO et al.

TABLE 4-3
Water Criteria: AWQC, Biota, and CRL[6]
(ppm)

Contaminant	BRI (1989) Water	EPA(1986b) AWQC		EBASCO (1989) CRL[7]
		Acute	Chronic	
Organic Chemicals				
Aldrin	**3.4E - 05**	3.0E - 03	--	7.0E - 05
B2EHP	--	9.4E - 01	**3.0E - 03**	--
DNBP	--	9.4E - 01	**3.0E - 03**	--
CPMSO	1.8E + 00	--	**2.0E - 03**	--
CPMSO2	1.8E + 00	--	**2.2E - 03**	--
Dieldrin	3.4E - 05	**1.9E - 06**	5.5E - 05	--
DDT/DDE	**1.0E - 06**	--	1.0E - 06	4.6E - 05
DIMP	2.6E + 00	--	6.0E - 01[1]	**1.0E - 02**
DMMP	5.1E - 01	--	--	**1.9E - 02**
Dithiane	3.4E + 00	--	--	**1.6E - 03**
Endrin	3.2E - 05	1.8E - 04	**2.3E - 06**	5.0E - 05
Isodrin	**3.2E - 05**	--	--	5.6E - 05
Malathion	**1.0E - 04**	--	1.0E - 04	8.0E - 03
Parathion	**1.3E - 05**	6.5E - 05	1.3E - 05	1.0E - 02
Dioxins/Furans	--	1.0E - 05[2]	**1.0E - 08**[2]	--
Metals				
Arsenic III	1.0E - 01	8.5E - 01	4.8E - 02	**2.5E - 03**
Arsenic V		3.6E - 01	1.9E - 01	
Antimony	--	9.0E + 00	**1.6E + 00**	--
Barium	--	>50[5]	**1.0E + 00** (human MCL)	--
Beryllium	--	1.3E - 01	**5.3E - 03**	--
Cadmium [8]	7.6E - 04	3.9E - 03	**5.5E - 04**[3] 1.1E - 03	5.2E - 03
Chromium VI	--		1.1E - 02	**6.0E - 03**
Copper[8]	6.5E - 03	1.8E - 02	**5.4E - 03**[3] 1.2E - 02	7.9E - 03
Lead[8]	--	8.2E - 02	**9.9E - 04**[3] 3.2E - 03	1.9E - 02
Nickel +	--	1.4E + 00	**7.3E - 02**[3] 1.6E - 01	--
Silver +	--	4.1E - 03	8.4E - 04 **1.2E - 04**	
Mercury	1.6E - 05 4.0E - 06[4]	2.4E - 03	1.2E - 05	3.6E - 04
Thallium	--	1.4E + 00	**4.0E - 02**	--

TABLE 4-3
(continued)

[1]   Human SNARL criteria (CRWQCB, 1989)
[2]   Insufficient data to develop criteria, value presented is the Lowest Observed Effects Level (LOEL) (EPA, 1986b)
[3]   Four-day average (CRWQCB, 1989)
[4]   Lowest value based on toxicity to aquatic life; 1.6E-05 criterion is based on the pathways analysis.
[5]   Standard applies to soluble form
[6]   Values in bold are the most conservative criteria
[7]   Lowest laboratory CRL value reported for organic compounds (EBASCO et al., 1989)
[8]   Hardness dependent criteria 3.0)

MCL = Maximum Contaminant Level for human drinking water (EPA, 1986b)
-- no criteria available

1989a). Based on these values, use of EPA AWQC standards in this risk assessment presents a conservative approach.

The BRI criteria were considered important to this risk assessment, as they were developed specifically for the evaluation of RMA contamination and are based on a multiple food chain approach and tissue concentrations correlating with health effects levels for RMA wildlife. The BRI approach provides a more comprehensive estimate of water criteria than EPA Final Residue Values, because the pathway analysis incorporates food habits information and can weight the importance of different dietary inputs. BRI criteria are the most conservative of the three available criteria for aldrin, DDT/DDE, isodrin, malathion, parathion and mercury (Table 4-3).

In the BRI, water criteria for the major contaminants of concern were used to produce a corresponding sediment criteria. For this risk assessment, if water criteria were met, then sediment levels were also assumed to be acceptable. Surface water and sediment were treated as an integrated media in the BRI. The "no effects" water criteria were used to produce a corresponding sediment value by using the soil-water partition coefficient normalized for organic carbon (K_{oc}) and the fraction of organic carbon in the sediments at RMA (f_{oc}). Criteria protective of biota consuming sediments were thus derived directly from the water criteria. Organisms protected by BRI water and soil criteria would thus not be at risk if exposed to sediments.

4.1.3 Vegetation Criteria

Contaminants in vegetation that are of the greatest concern are those that bioaccumulate, such as the pesticides. Specific criteria are not available for vegetation. However, bioaccumulation factors and phytotoxic effects were taken into consideration in the development of BRI soil criteria. The soil criteria, therefore, are protective of vegetation and organisms ingesting the vegetation grown on such soils. The BRI soil criteria can be used as a "no effects" criteria for vegetation and wildlife consuming such vegetation.

The BRI considered only the amount of contaminants taken up by vegetation from soil and not the amount of contaminants that would be deposited as particulate on the vegetation. For this risk assessment, the BRI terrestrial pathways approach for the eagle and kestrel was used to determine the potential risk from ingesting vegetation contaminated from particulate deposition. A BMF from vegetation to the eagle or kestrel was calculated by considering the terrestrial pathways equation without the BMF for soil. The

resultant concentration in the eagle or kestrel, based on the resultant deposition concentration on vegetation and the BMF, was compared to the MATC to determine the risk potential to wildlife from SQI emissions.

Because the pathways approach was only used for the major contaminants of concern in the BRI, it could only be applied to the following chemicals in this risk assessment: dieldrin/aldrin, arsenic, mercury, and endrin/isodrin. The BRI and this risk assessment used dieldrin and endrin to represent aldrin and isodrin because of the tendency for the former to convert to the latter in the environment. In the BRI, BMF for the single bald eagle terrestrial food chain starting with soil was less than one for arsenic, mercury, and endrin. Therefore, these chemicals were not likely to be concentrating in the terrestrial food chains, and the kestrel food web pathway was not applied (ESE 1989). For dieldrin/aldrin, the BMF was greater than one so a separate more conservative pathways approach was constructed based on the kestrel food web.

For this assessment, a single bald eagle terrestrial food chain starting with vegetation rather than soil was used. Removal of the bioaccumulation factors (BAFs) for soil results in the following equations for arsenic, endrin, and mercury:

arsenic

BMF = 3.5 x 0.08 = 0.28
Terrestrial Plants --> Small Mammals --> Bald Eagle

endrin/isodrin

BMF = 0.49 x 6.9 = 3.38
Terrestrial Plants --> Small Mammals --> Bald Eagle

mercury

BMF = 4.3 x 11 = 47.3
Terrestrial Plants --> Small Mammals --> Bald Eagle

Generally, the terrestrial ecosystem only accounts for 10 percent of the eagle's diet. On RMA, however, observations on the winter feeding behavior of eagles indicated that the terrestrial pathway made up 90

percent of the eagle's diet, so that the above BMF values should be adjusted. The adjusted BMF values for the above chemicals are: arsenic = 0.25; endrin = 3.0; and mercury = 42.6.

Since the total BMF values for endrin and mercury starting with plants are greater than one, biomagnification is occurring. Kestrel food web pathway models were not constructed for endrin and mercury in the BRI, however, and thus were not available for use in this risk assessment. For the purposes of this risk assessment, it was therefore assumed that the BMF for the kestrel pathway starting with plants is approximately four times that for the eagle pathway starting with plants. This assumption was based on the dieldrin BMF for the kestrel pathway (160.4) which was approximately four times that for the eagle pathway (39) starting with plants.

To evaluate the risk to bald eagles from chemical deposition on vegetation and subsequent bioaccumulation through prairie dogs, it was assumed that prairie dogs make up 90 percent of the eagle's diet, and that eagles are likely to feed anywhere within the prairie dog colonies. A weighted average chemical deposition concentration on live vegetation in the prairie dog colonies was used to evaluate risk, rather than a specific receptor point deposition concentration. By comparing the tissue concentration in the eagle (based on the weighted resultant biomass deposition concentration multiplied by the adjusted BMF) to the MATC in avian species, the potential for risk to eagles and all other wildlife based on chemical concentrations in vegetation can be determined.

In the BRI pathways analysis for dieldrin/aldrin, the BMF for the complete terrestrial pathway starting with soil was greater than one, so a separate, more conservative, pathways approach was constructed based on the kestrel food web. This approach, which included seven food transfer pathways originating from soil and ultimately terminating with the kestrel, was adapted for use in this risk assessment. The six kestrel pathways that included plants were used to evaluate the risk from ingesting vegetation. The six pathways equations used are as follows:

Pathway						TOTAL BMF
9.9 x 9.1					=	90
1. Plants --> Insects --> Kestrels						
10 x 9.1					=	91
2. Plants --> Birds --> Kestrels						
9.9 x 10 x 9.1					=	901

3. Plants --> Insects --> Birds --> Kestrels

    9.9   x   2.8   x   9.1   =   252

4. Plants --> Insects --> Reptiles --> Kestrels

    9.9   x   4.3   x   9.1   =   387

5. Plants --> Insects --> Mammals --> Kestrels

    4.3   x   9.1   =   39

6. Plants --> Mammals --> Kestrels

The total BMF of residues from each pathway is calculated by multiplying the BMF values for each trophic level and adding the BMFs for each pathway. The BMFs for each pathway, however, must be adjusted for the proportion of the lower trophic levels in the diet of the higher trophic levels.

For example, the kestrel's diet is composed of 16.4 percent small birds. The bird diet consists of 50 percent plants; therefore, the percent of contribution to the kestrel diet in pathway two is (0.164)(0.50) = 8.2 percent. The adjusted BMF from pathway two is then the BMF times the percent diet, or (91)(0.082) = 7.4. The seventh potential pathway (soil to earthworm, 4.1 percent of the diet) is not included in the calculation.

		Relative Proportion of Pathway in Diet			
Pathway	BMF	% Bird	% Mammal	% Kestrel Diet	Adjusted BMF
1)	90	--	--	51.8	46.6
2)	91	50	--	8.2	7.4
3)	901	25	--	4.1	36.95
4)	252	--	--	4.5	11.3
5)	387	--	50	13.65	52.8
6)	39	--	50	13.65	5.3

Total BMF = 160.4

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* The diet does not total 100 percent because the seventh pathway (earthworms→birds→kestrel) was not considered. This calculation is based on a kestrel diet of 16.4 percent birds, 51.8 percent insects, 27.3 percent mammals, and 4.5 percent reptiles (ESE 1989).

The "no effects" soil and vegetation concentrations that are derived from the kestrel food pathways are lower than that derived from the single terrestrial food chain in the bald eagle pathway analysis. The kestrel food web thus represents a more conservative approach to determining the potential risk from chemical deposition on vegetation and subsequent bioaccumulation through the higher trophic levels. Because of this more

conservative approach, criteria derived based on the kestrel pathway will be protective of all other avian species and wildlife.

To provide a conservative estimate of risk to kestrels from dieldrin/aldrin, it was assumed that kestrels spent all their time feeding close to the SQI and not averaged over all the prairie dog colonies. The maximum resultant deposition isopleth was thus chosen as the specific receptor point deposition concentration. By comparing the tissue concentration in the kestrel (based on the maximum biomass deposition concentration multiplied by the adjusted BMF) to the MATC in avian species, the potential for risk to the kestrel and all other wildlife based on chemical concentrations in vegetation can be determined.

The potential risk for the 23 indicator chemicals that have insufficient pathways data was determined by comparing each of the deposition concentrations in water and soil to available water and soil criteria. When chemical deposition concentrations were below the soil and water criteria, it was assumed that biomass deposition levels were not a risk to wildlife.

4.2 RISK CHARACTERIZATION

4.2.1 Inhalation

Inhalation or the direct air exposure route was not evaluated in the BRI. Based on the human health risk assessment (WCC 1990) the potential for adverse effects on biota by air exposure was considered to be low. In addition, there is little information on the effects on natural ecosystems from exposure to nonvolatile airborne contaminants. Inhalation at the point of maximum impact did not result in an unacceptable health impact to humans (WCC 1990). Because humans are considered by EPA to be one-hundred times more sensitive than animals on which tests were performed, there is a one-hundred fold safety factor incorporated into the risk estimates. Ecological receptors at RMA would have to be more than one-hundred times more sensitive than test animals in order for there to be any impact from the SQI. Inhalation health impacts are expected to be insignificant compared to potential impacts through water, soil, and vegetation media. Although wind-blown dust may provide potential exposure, this mechanism was also not considered to be significant. In the case of the bald eagle, a species of special concern, the eagle's potential risk from inhalation is decreased by the distance of the roost and feeding areas from the SQI. Chemical concentrations in the air at these areas are expected to be negligible.

4.2.2 Dermal Exposure

Dermal exposure values were not calculated in the BRI Report and are also not considered to be significant in this ecological risk assessment. Dermal toxicity criteria were not considered in the BRI because of the uncertainty in correlating dermal toxicity data under laboratory conditions (concentrated solutions, shaved skin of test animals) with toxicity under field conditions (generally dilute concentrations mixed with soil or water, contact with various body surfaces that can be covered with hair or are calloused). In the case of the bald eagle, dermal absorption through contact with contaminated soil or water was regarded as negligible risk since bald eagles typically perch and roost in trees rather than on the ground or in the water.

4.2.3 Terrestrial Pathway

Resultant concentrations from the SQI emissions were evaluated against the soil and vegetation criteria presented in Section 4.1. The terrestrial pathway results (soil and vegetation) are presented in the following sections.

4.2.3.1 Soil

Values for the maximum prairie dog impact area and the maximum SQI-derived soil concentrations are compared to CRL and BRI criteria in Tables 4-4 and 4-5. In each case, the SQI-derived soil concentrations at the area of greatest impact (1.22 g/m^2 deposition isopleth) are below both the CRL and BRI criteria. Chemical concentrations for the indicator chemicals are also below all soil criteria at the maximum prairie dog receptor area (0.11 g/m^2). For those metals with available CRL criteria, the maximum resultant soil concentrations are below the CRL criteria. In addition, metals concentrations are below the naturally occurring levels of metals in western soils and RMA soils from nonsource or uncontaminated areas (Table (4-2). Based on the above findings, soil concentrations of the indicator chemicals deposited from the SQI emissions present no risk to RMA wildlife.

No soil criteria were available to evaluate the risk from soil deposition of phthalates, dioxins, antimony, barium, beryllium, nickel, silver, and thallium. It was assumed for these chemicals that the aquatic criteria would be more conservative than terrestrial criteria. Therefore, chemical concentrations were considered to be of no risk to wildlife if concentrations for these chemicals in water did not exceed EPA AWQC. The risk evaluation for these chemicals is presented in Section 4.2.4

TABLE 4-4
Soil CRL and Deposition Concentrations (ppm)

	CRL Criteria[1]	Maximum Impact Area	Prairie Dog Receptor Area
Organic Chemicals (ppm)			
Aldrin	1.8E - 03	2.48E - 04	2.24E - 05
CPMSO	2.3E + 00	1.42E - 03	1.28E - 04
CPMSO2	2.4E + 00	1.83E - 04	1.65E - 05
Dieldrin	1.2E - 03	2.14E - 04	1.93E - 05
DDT/DDE	1.0E - 03	2.14E - 04	1.93E - 05
DIMP	5.0E - 02	8.71E - 07	7.88E - 08
DMMP	5.0E - 02	1.42E - 05	1.28E - 06
Dithiane	6.0E - 01	7.08E - 07	6.41E - 08
Endrin	1.0E - 03	4.22E - 06	3.82E - 07
Isodrin	1.1E - 03	1.40E - 05	1.27E - 07
Malathion	2.5E - 01	5.74E - 06	5.19E - 07
Parathion	2.5E - 01	7.72E - 07	7.05E - 08
Metals (ppm)			
Arsenic	2.5E + 00	5.87E - 02	5.31E - 03
Cadmium	5.1E - 01	6.38E - 02	5.77E - 03
Chromium	5.2E + 00	5.81E - 03	5.26E - 04
Copper	4.7E + 00	2.11E + 00	1.90E - 01
Lead	8.4E + 00	2.03E - 01	1.84E - 02
Mercury	5.0E - 02	3.71E - 02	3.36E - 03

(1) Values in bold are most conservative criteria

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TABLE 4-5
Soil BRI Criteria and Deposition Concentrations (ppm)

	BRI Criteria[1]	Maximum Impact Area	Prairie Dog Receptor Area
Organic chemcials (ppm)			
Aldrin	1.0E - 01	2.48E - 04	2.24E - 05
CPMSO	**9.7E - 01**	1.42E - 03	1.06E - 03
CPMSO2	**9.7E - 01**	1.83E - 04	1.36E - 04
Dieldrin	1.0E - 01	2.14E - 04	1.93E - 05
DDT/DDE	4.0E + 00	2.14E - 04	1.93E - 05
DIMP	1.58E + 01	8.71E - 07	7.88E - 08
DMMP[2]	--	1.42E - 05	1.28E - 06
Dithiane[2]	--	7.08E - 07	6.41E - 08
Endrin	9.2E + 00	4.22E - 06	3.82E - 07
Isodrin	9.2E + 00	1.40E - 05	1.27E - 06
Malathion	**2.5E - 02**	5.74E - 06	5.19E - 07
Parathion[2]	--	7.79E - 07	7.05E - 08
Metals (ppm)			
Arsenic	5.2E + 01	5.87E - 02	5.31E - 03
Cadmium	1.3E + 01	6.38E - 02	5.77E - 03
Copper	1.0E + 02	2.11E + 00	1.90E - 01
Mercury	1.1E + 00	3.71E - 02	3.36E - 03

[1] Values in bold are most conservative criteria
[2] Insufficient data to develop BRI soil criteria

4.2.3.2 Vegetation

The pathways approach was used to evaluate the potential risk to wildlife from the bioaccumulation of dieldrin/aldrin, arsenic, mercury and endrin/isodrin. This risk assessment approach assumed that organisms are in equilibrium with their environment and that they would be exposed over their lifetime to the chemicals deposited over the 1.5 years of SQI operations.

For the analysis of arsenic, mercury, and endrin, it was assumed that eagles are likely to feed at any location within the prairie dog colony and that prairie dogs make up 90 percent of the eagle's diet. Because it was assumed that eagles are likely to feed at any location within a prairie dog colony, a weighted biomass deposition concentration within the prairie dog colonies was used to calculate the resultant tissue concentration in the eagle. The eagle tissue concentration is the product of the BMF and the weighted average biomass deposition concentration for each chemical. The weighted average biomass deposition concentration is derived by averaging the area-weighted chemical deposition concentration for each colony within a particular isopleth. The colony areas were based on ESE (1988a) prairie dog data (Figure 1-2). Prairie dog colonies outside the 0.01 prairie dog isopleth were not included in this calculation. These data are shown in Table 4-6.

The eagle or kestrel tissue concentrations based on the pathways approach and the vegetation deposition concentrations were compared in Table 4-6 to the BRI MATC values to determine if the eagle or kestrel would be at risk. In each case, the resultant tissue concentrations, based on the pathways approach in the eagle (endrin, arsenic, mercury) or kestrel (dieldrin/aldrin), are lower than the MATC. Therefore, the eagle as well as all other terrestrial species are not considered to be at risk from vegetation ingestion.

Even though the total BMF starting with plants was greater than one for endrin and mercury, the kestrel pathway was not applied, as biomagnification for these chemicals in terrestrial pathways was not considered to be significant in the BRI and pathways models were therefore not available for use in this risk assessment. In order to consider the kestrel pathway, it was therefore assumed that the BMF for the kestrel pathway starting with plants is approximately four times that for the eagle pathway starting with plants based on the dieldrin pathway (Section 4.1.3). This is considered a conservative assumption in that endrin and mercury (II) are expected to bioaccumulate to a lesser extent than dieldrin.

Using this relationship for endrin results in a BMF of 12.1 and a resultant tissue concentration of 4.2E-04 ppm, using the maximum biomass deposition concentration of 3.48E-05 ppm. The resultant tissue

TABLE 4-6
Eagle and Kestrel Tissue Concentrations From Vegetation (ppm)

| Chemical | Adjusted BMF | Concentration | | MATC |
		Vegetation	Tissue	
endrin[1]	3.04	1.25E - 06	3.81E - 06	8.3E - 01
arsenic[1]	0.25	1.90E - 02	4.76E - 03	7.4E - 01
mercury[1]	42.6	1.21E - 02	5.13E - 01	8.0E - 01
dieldrin/aldrin[2]	144.4	1.76E - 03	2.54E - 01	1.0E + 01

[1] Eagle food transfer pathways.
[2] Kestrel food transfer pathways.

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concentration for endrin is well below the MATC for endrin of 8.3E-01 ppm. The kestrel, the eagle, and all other terrestrial species are therefore not considered to be at risk from vegetation ingestion.

For mercury, the BMF would become 170 and the resultant tissue concentration would be 52 ppm, using the maximum deposition concentration of 3.064E-01 ppm. The 52 ppm resultant tissue concentration is substantially greater than the 8.0E-01 ppm MATC value selected in the BRI. Neither of these values, however, may be realistic given the following considerations:

- The 8.0E-01 ppm MATC value was the lowest tissue (mallard muscle) concentration that could be correlated with toxic effects from methyl mercury. Methyl mercury is far more toxic and more readily accumulated than the inorganic mercury (II) form that would be emitted by the SQI.

- The BAFs used in the BRI pathways equation were based on data for methyl mercury, not inorganic mercury. If the lower BAF value (1.14) reported in the BRI for sheep grazing on contaminated vegetation was used as a more realistic value, rather than usir the BAF for mink fed a commercial diet with methyl mercury, then the resultant BMF for the eagle would be 1.14 (vegetation -> mammal) times 11 (mammal -> eagle) for a total BMF of 12.54. Using a BMF four times that of the eagle, the kestrel BMF would then be 50.1 and the resultant tissue concentration would be 3.85 ppm.

- Use of maximum deposition concentration on biomass is overly conservative in the case of the kestrel. Given the location of the active kestrel boxes on RMA, the 0.11 isopleth (2.77E-02 ppm) would be more reasonable to use as the area of maximum deposition in which kestrels feed. Using a BMF of 12.54, the resultant tissue concentration becomes 3.4E-01 ppm which is below the mallard MATC (8.0E-01 ppm) for methyl mercury.

Several additional factors can be considered in the determination of potential risk to terrestrial species from mercury. The calculation of the mercury deposition concentration on vegetation (Section 3.4.3) was made using a number of very conservative assumptions. The percent live plant cover on which particulates were deposited and biota ingested was assumed to be 50 percent for the 1.5 years of SQI operations. Percent live plant cover is typically measured in the summer at the peak of live growth; therefore the 50 percent value is likely to be unrealistically representative. Also, most of the live vegetation consists of annual species which would be present for approximately 0.50 to 0.75 years and would therefore not receive the full 1.5 years of particulate deposition. Furthermore, inorganic mercury is perhaps more likely to remain adsorbed to

particulate and be washed off the plants than remain on or be absorbed by the plants. Given a conservative 10 percent reduction in the biomass deposition value, the resultant tissue concentration using the above procedure for the kestrel becomes 3.5E-02 ppm, well below the MATC value for methyl mercury.

The risk to kestrel and higher trophic level species which feed primarily on vegetation and terrestrial food sources can be considered minimal. Based on the above analysis, the kestrel, the eagle, and all other terrestrial species are not considered to be at risk or likely to be affected unacceptably by chemicals emitted from the SQI and deposited on vegetation.

The potential risk for the remaining 23 chemicals was determined by comparing each of the water or soil deposition concentrations to the available water and soil criteria. Because each of these chemical deposition concentrations is below identified soil and water criteria, the resultant biomass deposition levels are also considered to present no risk to wildlife.

4.2.4 Aquatic Pathway

Deposition concentrations for all chemicals except mercury are below the AWQC and CRL criteria at each of the three aquatic receptor points, North Bog, Lower Derby Lake, and First Creek. These data are shown in Table 4-7. The resultant chemical concentrations except mercury at the three receptor water bodies are also below the BRI water criteria and are therefore considered to be of no risk to the bald eagle, kestrel, or any other species feeding on aquatic organisms. Resultant mercury water concentrations at the receptor points greater than the criteria. This required closer examination of potential mercury-related risks.

Surface water mercury concentrations are above but within the same order of magnitude of the AWQC (1.2E-05 ppm) at North Bog (0.06 g/m² deposition isopleth; 3.97E-05 ppm), First Creek (0.05 g/m² deposition isopleth; 3.31E-05 ppm), and Lower Derby Lake (0.03 g/m² deposition isopleth; 1.98E-05 ppm). Surface water mercury concentrations are also slightly above but within the same order of magnitude of the BRI criterion for mercury (1.6E-05 ppm) which was developed based on the pathways analysis. Surface water mercury concentration at the three aquatic receptor points are well above the BRI criterion of 4.0E-06 ppm which is based on the toxicity of methylmercury to aquatic life. Mercury concentrations are below the CRL criterion (3.6E-04 ppm) at these same locations.

The modeled surface water deposition concentration of mercury at Lower Derby Lake (1.98E-05 ppm) is essentially the same as the AWQC for mercury (1.2E-05 ppm). Given that Lower Derby Lake is deeper

TABLE 4-7

Water Quality Criteria and SQI-Related Concentrations at the Nearest Water Receptor Locations (ppm)[1]

	EPA/AWQC	CRL	BRI	North Bog	First Creek	Lower Derby Lake
Organic Chemicals						
Aldrin	3.0E - 03	7.0E - 05	3.4E - 05	2.64E - 07	2.20E - 07	1.32E - 07
B2EHP+	3.0E - 03	--	--	1.10E - 04	9.14E - 05	5.49E - 05
DNBP+	3.0E - 03	--	--	1.48E - 04	1.23E - 04	7.40E - 05
CPMSO	--	2.0E - 03	1.8E + 00	1.51E - 06	1.26E - 06	7.57E - 07
CPMSO2	--	2.2E - 03	1.8E + 00	1.95E - 07	1.27E - 07	9.76E - 08
Dieldrin	1.9E - 06	5.5E - 05	3.4E - 05	2.28E - 07	1.90E - 07	1.14E - 07
DDT/DDE	1.0E - 06	4.6E - 05	1.0E - 06	2.28E - 07	1.90E - 07	1.14E - 07
DIMP	6.0E - 01	1.0E - 02	2.6E + 00	9.31E - 10	7.76E - 10	4.65E - 10
DMMP	--	1.9E - 02	5.1E - 01	1.51E - 08	1.26E - 08	7.57E - 09
Dithiane	--	1.6E - 03	3.4E + 00	7.57E - 10	6.31E - 10	3.78E - 10
Endrin	2.3E - 06	5.0E - 05	3.2E - 05	4.51E - 09	3.76E - 09	2.26E - 09
Isodrin	--	5.6E - 05	3.2E - 05	1.50E - 08	1.25E - 08	7.49E - 09
Malathion	1.0E - 04	8.0E - 03	1.0E - 04	6.13E - 09	5.11E - 09	3.06E - 09
Parathion	1.3E - 05	1.0E - 02	1.3E - 05	8.32E - 10	6.94E - 10	4.16E - 10
dioxin/furan	1.0E - 08	--	--	9.93E - 11	8.28E - 11	4.97E - 11
Metals						
Arsenic	4.8E - 02	2.5E - 03	1.0E - 01	6.27E - 05	5.22E - 05	3.13E - 05
Antimony	1.6E + 00	--	--	1.67E - 04	1.39E - 04	8.37E - 05
Barium	1.0E + 00	--	--	2.04E - 04	1.70E - 04	1.02E - 04
Beryllium	5.3E - 03	--	--	1.57E - 06	1.31E - 06	7.84E - 07
Cadmium	5.5E - 04	5.2E - 03	7.6E - 04	6.82E - 05	5.68E - 05	3.41E - 05
Chromium	1.1E - 02	6.0E - 03	--	6.21E - 06	5.17E - 06	3.10E - 06
Copper	5.4E - 03	7.9E - 03	6.5E - 03	2.250E - 03	1.87E - 03	1.13E - 03
Lead	9.9E - 04	1.9E - 02	--	2.17E - 04	1.81E - 04	1.08E - 04
Nickel	7.3E - 02	--	--	5.01E - 05	4.17E - 05	2.50E - 05
Silver	1.2E - 04	--	--	3.15E - 06	2.62E - 06	1.57E - 06
Mercury	1.2E - 05	3.6E - 04	4.0E - 06	3.97E - 05	3.31E - 05	1.98E - 05
Thallium	4.0E - 02	--	--	6.27E - 05	5.22E - 05	3.13E - 05

(1) Values in Bold are the most conservative criteria

(2001-375)(LPA(11847.WK11)(07/06/90).1

than the 12 inches used to calculate the deposition concentration and because mixing occurs, the resultant deposition concentration would be expected to be less than the AWQC or BRI criteria, particularly over the 1.5 year exposure duration of contaminant deposition. The BRI criterion is particularly conservative in evaluating these lakes, as it is based on the assumption of equilibrium and does not account for the addition of rain and surface water flow to the lakes.

Resultant mercury concentrations in First Creek do not present a risk because of slow dilution. Although the maximum resultant surface deposition concentration for First Creek (0.05 g/m^2 isopleth; 3.31E-05 ppm) is slightly above the AWQC and exceeds the BRI criteria, the deposition concentration does not account for the diluting effects of intermittent flowing water (the concentration was calculated as though First Creek was a stationary water body). Given this additional factor, it is unlikely that the resultant deposition concentrations would exceed the criteria or present any adverse risk to aquatic life.

The modeled surface water mercury concentration at North Bog (0.06 g/m^2 isopleth; 3.97E-05 ppm) exceeds the AWQC (1.2E-05 ppm) and BRI criteria (4.0E-06 ppm). Again because the surface water concentration is based on an accumulative 1.5-year deposition in a water body that has both a diluting inflow and outflow, the actual mercury concentration is not expected to exceed the EPA acute or chronic 24-hr AWQC. Although the North Bog remains a relatively shallow water body, generally not more than 1 ft deep, the level does fluctuate, reflecting groundwater levels in the vicinity of the bog. Water levels in the bog are also influenced by recharge components operations at the North Boundary Containment System. Currently the bog is receiving 4.3 gpm due to recharge operations.

Although the inorganic mercury deposition level at North Bog slightly exceeds the EPA AWQC for methylmercury, it was conservatively assumed in this assessment that all mercury is dissolved, which is unlikely in a carbonaceous particulate matrix. EPA AWQC guidelines for mercury also state that if the 4-day average concentration of mercury does no exceed 1.2E-05 ppm more than once every 3 years on average and if the 1 hour average concentration does not exceed 2.4E-03 ppm more than once every 3 years on average, freshwater aquatic organisms and their uses should be protected. Given the 1.5 year timeframe over which deposition from the SQI will occur, it seems unlikely that EPA AWQC would be exceeded at North Bog or that aquatic organisms and their uses would be affected unacceptably.

Additional consideration should be given to the fact that the EPA AWQC (1.2E-05 ppm) and the BRI criteria based on the food web pathways analysis (1.6E-05 ppm) are based on the assumption that all mercury present is in the form of methylmercury which has a BCF that is 10 to 20 times greater than that

for inorganic mercury (II), the form deposited by the SQI. For the EPA AWQC, the freshwater criterion is based on a final residue value of 1.2E-05 ppm which is derived from a bioconcentration factor of 81,700 for methylmercury with fathead minnow. EPA toxicity data for mercury (II) indicate a chronic toxicity value for Daphnia magna of 1.1E-03 ppm and for fathead minnows of 2.3E-04 ppm (EPA 1986b). The AWQC guidance value for mercury(II) is 2.0E-04 ppm.

Site-specific BRI criteria for the protection of aquatic life are based on the lowest reported chronic value and are more conservative than EPA values. Adverse effects (LOAEL) were observed in Daphnia magna during chronic exposure to 4.0E-05 ppm methylmercury. A NOEL acceptable water concentration of 4.0E-06 ppm was derived by applying an uncertainty factor of 10. This value was lower than the pathways analysis value (1.6E-05 ppm) and was used as the BRI aquatic criterion for protection of all wildlife. The BRI criterion is based on methylmercury and is overly conservative for assessing the risk from mercury (II). This conclusion is based on the chronic value obtained by EPA with Daphnia magna for mercury (II) (1.1E-03 ppm). Given that the SQI disposition value is below the AWQC guideline for mercury (II) by an order of magnitude nor does it exceed the BRI LOAEL for methyl mercury, organisms and their uses at North Bog should not be affected unacceptably.

It is possible that the inorganic mercury deposited by the SQI will be converted to methylmercury in the lake and bog sediments. The transformation of mercury (II) to organic methylmercury forms, however, is a slow process minimized by low microbial alkylation rates as well as by the expected binding of particulate matter to sediments. The rate of microbial biotransformation occurring under RMA conditions reportedly is less than 1.5 percent per month (Jensen and Jernelov 1969, in ESE 1989).

Fish fillets obtained from Lower Derby Lake and Lake Eldora were analyzed for mercury. The BRI concluded that the mercury in the fish had come from a methylmercury source rather than environmental sources of inorganic mercury (ESE 1989). If all of the available mercury in the existing lake sediment (up to 18 ppm) were available as methylmercury, the resulting mercury concentration in fish fillets would be much higher based on a BCF of 3000 (Johnels et.al. 1967, and ESE 1989).

Based on a BCF of 3000 and assuming that all SQI deposited mercury is available as methylmercury, the fish tissue level in using the maximum particulate deposition at the closest water body (North Bog, 3.97E-05 ppm) would be 0.12 ppm, which is less than the FDA action level of 1 ppm. By considering the FDA action level in fish tissue as a criterion, mercury concentrations resulting from SQI emissions would not present

a human health risk. Humans are assumed to be one hundred times more sensitive to chemical toxicities than the animals that are tested.

The aqueous mercury concentration at the highest impacted lake (3.97E-05 ppm) also assumed that all of the mercury present would become dissolved when the particulate settled into the water. The particulate matter is only 0.0139 percent mercury with the remainder consisting of a mineral and elemental carbon matrix. The likely fate of the particulate is that it will settle to the bottom of the lake and become entrapped in the sediment. The deposition of additional sediment will result in average sediment concentrations similar to the surface soil concentrations calculated for soil deposition. At the North Bog, the sediment (soil) mercury concentrations resulting from the SQI would be 1.83E-03 ppm. This value is much lower than the range of mercury concentrations recently found in Lower Derby Lake and Lake Ladora sediments, 5.30E-02 to 1.80E+01 ppm (EBASCO 1989a). It is concluded that the SQI lake sediment (soil) mercury concentration of 1.83-03 ppm will not pose an ecological health risk based on the above analysis.

It is necessary to make assumptions for any risk assessment. Identification of assumptions and subsequent uncertainties and their impact on estimated risks helps to place the risk estimates in perspective. High uncertainty (low confidence, low level of information) indicates that a value is less accurate and more likely to change, given more information. Low uncertainty (high confidence) is an indication that a value is more accurate and less likely to change as more data become available. A range of possible assumptions exists which can be used to represent any given uncertainty. Realistic assumptions are generally those about which a significant amount of information is known, or have a low level of uncertainty.

In the absence of adequate information, the approach used in this risk assessment was to make conservative assumptions to ensure that risks are not underestimated. Assumptions were made in the initial selection of indicator chemicals, the exposure assessment, and in the risk characterization. When many conservative assumptions are used to develop an overall assessment of risk, the sum of the effect results in an overly conservative risk estimate. The actual incremental risks are likely to be lower than these estimates, and may even be zero. The major assumptions and those which tend to overestimate risks are presented below with some discussion of their uncertainty, conservativeness, or impact on risk.

5.1 FACTORS WHICH MAY OVERSTATE RISK

A number of assumptions were made in the BRI report with respect to the pathways analysis approach. The BRI-derived criteria were used in this risk assessment as reported. The pathways analysis is a theoretical calculation involving many input parameters, each of which is known imprecisely. For several of the contaminants, data were unavailable for parameters such as loss rates or assimilation efficiencies. In these cases, judgement was used in the BRI to select the best data available from which to derive the parameters, and assumptions were made that the parameters are applicable to all species in the analysis. Because the data were often based on laboratory experiments that have not been validated in the field, and arbitrary uncertainty factors were applied, the parameters used in the BRI toxicity assessment were conservative. Other assumptions, such as organisms being in equilibrium with their environment, are also very conservative and were used only as a first approximation. The combined effect from the uncertainty in each of the parameters and assumptions used in the final estimate of the biomagnification factors may overstate the risk.

This risk assessment was based on the assumption that all organisms are in equilibrium with their environment. This is a common assumption used for modeling purposes. While this assumption does not account for the inevitable flux of chemicals in the environment and the creation of hot and cold spots, it is nevertheless a conservative assumption in that it also does not account for the mobility of most animal species and the unlikelihood that they would remain in hot spots long enough for effects to occur.

Even though dioxins and furans were not detected in the stack gas they were assumed to be emitted at detection limit concentrations and were assumed to be present as the most toxic isomer, 2,3,7,8-tetrachlorodibenzodioxin (TCDD).

The risk to the eagle from soil deposition was overly conservative in assuming that the eagle's diet is 90 percent prairie dogs. Since the plague at RMA, prairie dogs can be expected to make up a smaller percentage of the eagle's diet.

Soil chemical concentrations were calculated using low density values for soil. The calculation of the resultant soil deposition concentration is conservative in that it excludes any deposition onto vegetation. This means that some deposited particulate was counted more than once. Using the maximum deposition isopleth to evaluate risks from the soil media results in an overly conservative approach due to the small area involved.

It was conservatively assumed that chemicals from the SQI are expected to mix with the first ¼ to ½-inch of soil. This assumption was made in order to evaluate maximum risk to biota from contaminants in the soil. In reality, the deposited chemicals and particulate are likely to be transferred offpost through windblown erosion. This assumption allows an upperbound risk estimate to be made.

The 50 percent cover and 100 g/m^2 dry biomass values used to calculate resultant particulate deposition in biomass were conservative. The chemicals evaluated in this risk assessment are not particularly mobile through plant leaves and are likely to be washed or blown off onto surrounding soil rather than ingested by wildlife. In addition, the eagles are present at RMA and feed on prairie dogs for 5 to 7 months a year, rather than the entire 1.5-year project duration.

Surface water deposition concentrations were conservatively calculated on the basis of a 12-inch water depth with no dilution from inflow.

The BRI criteria for water were based on a conservative assumption of equilibrium, which does not account for inflow or dilution from the rain. The site-specific BRI criteria for water may also be unrealistically low, because it was assumed in the BRI report that the aquatic food chain supplies 100 percent of a bald eagle's diet. Prairie dogs are actually the major portion of the eagle's diet at RMA. In addition, the lakes are likely to be frozen part of the period when eagles are present.

The weighted average concentration used for the biomass deposition provides a conservative estimate of exposure for the eagle. The weighted average concentration is equivalent to chemical deposition concentrations which would occur within the 0.04 isopleth. Most of the eagle feeding locations are east of First Creek and outside the 0.03 isopleth, which results in a lower exposure than the weighted average value.

The weighted average biomass concentration for eagles did not include prairie dog colonies outside of the 0.01 $g/m^2/yr$ particulate deposition isopleths which are located on the RMA.

The area of maximum particulate deposition was selected as the exposure receptor point for the kestrel in order to provide a conservative estimate of the potential for contaminants to be transported through the food chain to the kestrel. This is an overly conservative estimate due to the small (50 square meters) area involved.

5.2 FACTORS WHICH MAY UNDERSTATE RISK

Dermal and inhalation exposure routes were not evaluated. Contaminated soil adhering to animal's skin or particulate that is directly inhaled might result in increased exposure and risk. Although these routes could be significant for animals whose range is limited to the 50 square meter area of maximum deposition, these routes were judged not to be significant compared to the ingestion exposure route. This exposure point was used to evaluate human health risks by inhalation. There were no unacceptable health risks to humans at this exposure point and humans are assumed to be one hundred times more sensitive than test animals used to determine toxicities.

This risk evaluation did not take into account accident or spill scenarios associated with the operation of the SQI or in the transfer of liquids by pipeline to the SQI.

The potential adverse environmental effects associated with operation of the SQI incinerator were evaluated according to EPA environmental risk assessment guidelines (EPA 1989). Twenty-nine chemicals that represent the most toxic, environmentally mobile, or those present in the highest concentrations were evaluated for potential adverse effects to terrestrial and aquatic wildlife and vegetation on RMA. Assumptions used in this ecological risk assessment were conservative in that they are protective of the environment and may result in an overestimate of the actual risks.

A variety of criteria was used to evaluate risks to the environment in this assessment. These criteria included EPA AWQC, site-specific criteria developed in the BRI for the protection of RMA wildlife, particularly the bald eagle, and the CRLs used in the RMA Remedial Investigation Contamination Assessment and Study Area Reports. The bald eagle was used as the primary indicator species for the evaluation of ecological risk in this assessment. It was selected following EPA guidelines as an endangered species and one of special concern at RMA, in addition to its position at the highest trophic level in the wildlife food chain.

The ingestion pathway is the greatest contributor to the risks associated with wildlife exposure. The criteria used for the evaluation of risk from ingesting soil, water, and vegetation media were based on the effects of direct ingestion as well as those from bioaccumulation through the food chain. Criteria for the evaluation of risk from ingesting vegetation were specifically developed for this ecological assessment and were based on the terrestrial pathways approach presented in the BRI.

Chemical concentrations in soil, biomass, and water resulting from SQI emissions deposition were compared against available criteria at selected receptor exposure points. The deposition chemical concentrations in soil, water, and vegetation were below the criteria for all chemicals except mercury.

The calculated mercury concentrations at the aquatic receptor exposure points assumed that all mercury in the particulate dissolved in the water (North Bog, First Creek, and Lower Derby Lake). Using this extremely conservative assumption, the mercury concentrations are slightly above the EPA AWQC and BRI criteria for protection of aquatic organisms. Several real world phenomena would result in lower mercury concentrations than is estimated using the above conservative assumptions. These include dilution, the short exposure period (1.5 years), and that mercury will actually be deposited in the form of mercuric II (as an

oxide) rather than the more toxic methylmercury form upon which EPA and BRI criteria are based. A more realistic pathway for mercury release when particulate is deposited on RMA lakes or ponds is to assume that the particulate and mercury are incorporated into the lake sediment. The resulting sediment mercury concentrations are orders of magnitude lower than existing sediment mercury concentrations.

Based on this assessment, it is concluded that the operation of the SQI incinerator poses no quantifiable risks to the wildlife and vegetation at RMA.

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AWQC -	Ambient Water Quality Criteria
B2EHP -	bis-2-(ethylhexyl) phthalate
BCF -	Bioconcentration Factor
BMF -	Biomagnification Factors
BRI -	Biota Remedial Investigation
CAR -	Contamination Assessment Report
CPMS -	chlorophenylmethylsulfide
CPMSO -	chlorophenylmethylsulfoxide
CPMSO2 -	chlorophenylmethylsulfone
CRL -	Certified Reporting Limit
DBCP -	dibromochloropropane
DCPD -	dicyclopentadiene
DD -	Deposition Duration
DDE -	1,1-dichloro-2,2-bis(4-chlorophenyl)-ethylene
DDT -	dichlorodiphenyltrichloroethane
DIMP -	diisopropylmethylphosphonate
DMMP -	dimethylmethylphosphonate
DNBP -	di-n-butyl phthalate
EMF -	Ecological Magnification Factor
EPA -	Environmental Protection Agency
ESE -	Environmental Science and Engineering
g/m^2 -	grams per square meter
HCCPD -	hexachlorocyclopentadiene
hex -	hexavalent chromium
HxCDD -	hexachlorodibenzodioxin
ISC -	Industrial Source Complex
ISCLT -	Industrial Source Complex Long-Term
kg/m^3 -	kilograms per cubic meter
Koc -	organic carbon partition coefficient
Kow -	octanol-water partition coefficient

LOAEL -	Lowest Observed Adverse Effects Level
LOEL -	Lowest Observed Effects Level
MATC -	Maximum Allowable Tissue Concentration
MCL -	Maximum Contaminant Level for human drinking water
mg/l -	milligrams per liter
msl -	mean sea level
NOEL -	No Observed Effects Level
PCBs -	polychlorinated biphenyls
PeCDD -	pentachlorodibenzodioxin
ppb -	parts per billion
ppm -	parts per million
RI -	Remedial Investigation
RMA -	Rocky Mountain Arsenal
RPD -	Rate of Particulate Deposition
SAR -	Study Area Report
SCS -	Soil Conservation Service
SEAM -	Superfund Exposure Assessment Manual
SPHEM -	Superfund Public Health Evaluation Manual
SQI -	Submerged Quench Incinerator
TCDD -	tetrachlorodibenzodioxin
TCE -	trichloroethylene
UCF -	Unit Conversion Factor
USFWS -	U.S. Fish and Wildlife Service

TABLE · · DEPOSITION IMPACTS FROM SOI AT PARTICULATE DEP OF 0.01 GM/M2-YR · STAPLETON (1988)

COMPOUND	EMISSION RATE (G/SEC)	ANN. IMPACT COMPOUND DEPOSITION (GM/M2-YR)	RESULTANT SOIL CONC (MG/KG)	RESULTANT BIOMASS CONC (MG/KG)	RESULTANT SFC WATER CONC (MG/L)
endrin	6.216E-09	1.527E-10	3.471E-08	2.864E-07	7.516E-10
isodrin	2.065E-08	5.074E-10	1.153E-07	9.513E-07	2.497E-09
bis (2-Ethylhexyl) phthalate	1.512E-04	3.715E-06	8.443E-04	6.966E-03	1.828E-05
Di-n-butylphthalate	2.039E-04	5.010E-06	1.139E-03	9.393E-03	2.465E-05
aldrin	3.644E-07	8.953E-09	2.035E-06	1.679E-05	4.406E-08
dieldrin	3.147E-07	7.732E-09	1.757E-06	1.450E-05	3.805E-08
4,4' - DDT	3.147E-07	7.732E-09	1.757E-06	1.450E-05	3.805E-08
4,4' - DDE	3.147E-07	7.732E-09	1.757E-06	1.450E-05	3.805E-08
TCDD	1.369E-10	3.364E-12	7.645E-10	6.307E-09	1.655E-11
PeCDD	3.305E-10	8.120E-12	1.846E-09	1.523E-08	3.996E-11
HxCDD	4.721E-10	1.160E-11	2.636E-09	2.175E-08	5.708E-11
pentachlorodibenzofuran	9.756E-10	2.397E-11	5.448E-09	4.494E-08	1.180E-10
tetrachlorodibenzofuran	6.378E 10	1.567E-11	3.562E-09	2.938E-08	7.712E-11
hexachlorodibenzofuran	6.287E-09	1.545E-10	3.511E-08	2.896E-07	7.602E-10
4-chlorophenyl methylsulfoxide	2.086E-06	5.125E-08	1.165E-05	9.610E-05	2.522E-07
4-chlorophenyl methylsulfone	2.691E-07	6.612E-09	1.503E-06	1.240E-05	3.254E-08
diisopropyl methylphosphonate	1.283E-09	3.152E-11	7.164E-09	5.911E-08	1.551E-10
dimethyl methylphosphonate	2.086E-08	5.125E-10	1.165E-07	9.610E-07	2.522E-09
dithiane	1.043E-09	2.563E-11	5.824E-09	4.805E-08	1.261E-10
malathion	8.448E-09	2.076E-10	4.717E-08	3.892E-07	1.021E-09
parathion	1.147E-09	2.818E-11	6.405E-09	5.284E-08	1.387E-10
particulate	4.070E-01	1.000E-02	2.273E+00	1.875E+01	4.921E-02
arsenic	8.637E-05	2.122E-06	4.823E-04	3.979E-03	1.044E-05
antimony	2.306E-04	5.666E-06	1.288E-03	1.062E-02	2.788E-05
barium	2.818E-04	6.924E-06	1.574E-03	1.298E-02	3.407E-05
beryllium	2.161E-06	5.310E-08	1.207E-05	9.955E-05	2.613E-07
cadmium	9.393E-05	2.308E-06	5.245E-04	4.327E-03	1.136E-05
chromium	8.555E-06	2.102E-07	4.777E-05	3.941E-04	1.034E-06
copper	3.100E-03	7.617E-05	1.731E-02	1.428E-01	3.748E-04
lead	2.989E-04	7.344E-06	1.669E-03	1.377E-02	3.614E-05
nickel	6.902E-05	1.696E-06	3.854E-04	3.180E-03	8.346E-06
silver	4.339E-06	1.068E-07	2.423E-05	1.999E-04	5.247E-07
thallium	8.637E-05	2.122E-06	4.823E-04	3.979E-03	1.044E-05
mercury	5.468E-05	1.343E-06	3.053E-04	2.519E-03	6.612E-06

TABLE - - DEPOSITION IMPACTS FROM SQI AT PARTICULATE DEP OF 0.02 GM/M2-YR - STAPLETON (1988)

COMPOUND	EMISSION (G/SEC)	ANN. IMPACT COMPOUND DEPOSITION (GM/M2-YR)	RESULTANT SOIL CONC (MG/KG)	RESULTANT BIOMASS CONC (MG/KG)	RESULTANT SF WATER CONC (MG/L)
endrin	6.216E-09	3.055E-10	6.942E-08	5.727E-07	1.503E-09
isodrin	2.065E-08	1.015E-09	2.306E-07	1.903E-06	4.994E-09
bis (2-Ethylhexyl) phthalate	1.512E-04	7.430E-06	1.689E-03	1.393E-02	3.656E-05
Di-n-butylphthalate	2.039E-04	1.002E-05	2.277E-03	1.879E-02	4.931E-05
aldrin	3.644E-07	1.791E-08	4.070E-06	3.357E-05	8.812E-08
dieldrin	3.147E-07	1.546E-08	3.515E-06	2.900E-05	7.610E-08
4,4' - DDT	3.147E-07	1.546E-08	3.515E-06	2.900E-05	7.610E-08
4,4' - DDE	3.147E-07	1.546E-08	3.515E-06	2.900E-05	7.610E-08
TCDD	1.369E-10	6.727E-12	1.529E-09	1.261E-08	3.311E-11
PeCDD	3.305E-10	1.624E-11	3.691E-09	3.045E-08	7.993E-11
HxCDD	4.721E-10	2.320E-11	5.273E-09	4.350E-08	1.142E-10
pentachlorodibenzofuran	9.756E-10	4.794E-11	1.090E-08	8.989E-08	2.359E-10
tetrachlorodibenzofuran	6.378E-10	3.134E-11	7.123E-09	5.877E-08	1.542E-10
hexachlorodibenzofuran	6.287E-09	3.089E-10	7.021E-08	5.793E-07	1.520E-09
4-chlorophenyl methylsulfoxide	2.086E-06	1.025E-07	2.330E-05	1.922E-04	5.045E-07
4-chlorophenyl methylsulfone	2.691E-07	1.322E-08	3.005E-06	2.479E-05	6.508E-08
diisopropyl methylphosphonate	1.283E-09	6.305E-11	1.433E-08	1.182E-07	3.103E-10
dimethyl methylphosphonate	2.086E-08	1.025E-09	2.330E-07	1.922E-06	5.045E-09
dithiane	1.043E-09	5.125E-11	1.165E-08	9.610E-08	2.522E-10
malathion	8.448E-09	4.151E-10	9.435E-08	7.784E-07	2.043E-09
parathion	1.147E-09	5.636E-11	1.281E-08	1.057E-07	2.774E-10
particulate	4.070E-01	2.000E-02	4.545E+00	3.750E+01	9.843E-02
arsenic	8.637E-05	4.244E-06	9.646E-04	7.958E-03	2.089E-05
antimony	2.306E-04	1.133E-05	2.575E-03	2.125E-02	5.577E-05
barium	2.818E-04	1.385E-05	3.147E-03	2.596E-02	6.815E-05
beryllium	2.161E-06	1.062E-07	2.415E-05	1.991E-04	5.226E-07
cadmium	9.393E-05	4.616E-06	1.049E-03	8.654E-03	2.272E-05
chromium	8.555E-06	4.204E-07	9.554E-05	7.682E-04	2.069E-06
copper	3.100E-03	.1.523E-04	3.462E-02	2.856E-01	7.497E-04
lead	2.989E-04	1.469E-05	3.338E-03	2.754E-02	7.228E-05
nickel	6.902E-05	3.392E-06	7.708E-04	6.359E-03	1.669E-05
silver	4.339E-06	2.132E-07	4.846E-05	3.998E-04	1.049E-06
thallium	8.637E-05	4.244E-06	9.646E-04	7.958E-03	2.089E-05
mercury	5.468E-05	2.687E-06	6.107E-04	5.058E-03	1.322E-05

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TABLE - - DEPOSITION IMPACTS FROM SQI AT PARTICULATE DEP OF 0.03 GM/M2-YR - STAPLETON (1988)

COMPOUND	EMISSION RATE (G/SEC)	ANN. IMPACT COMPOUND DEPOSITION (GM/M2-YR)	RESULTANT SOIL CONC (MG/KG)	RESULTANT BIOMASS CONC (MG/KG)	RESULTANT SFC WATER CONC (MG/L)
endrin	6.216E-09	4.582E-10	1.041E-07	8.591E-07	2.255E-09
isodrin	2.065E-08	1.522E-09	3.459E-07	2.854E-06	7.491E-09
bis (2-Ethylhexyl) phthalate	1.512E-04	1.114E-05	2.533E-03	2.090E-02	5.485E-05
Di-n-butylphthalate	2.039E-04	1.503E-05	3.416E-03	2.818E-02	7.396E-05
aldrin	3.644E-07	2.686E-08	6.105E-06	5.036E-05	1.322E-07
dieldrin	3.147E-07	2.320E-08	5.272E-06	4.349E-05	1.142E-07
4,4' - DDT	3.147E-07	2.320E-08	5.272E-06	4.349E-05	1.142E-07
4,4' - DDE	3.147E-07	2.320E-08	5.272E-06	4.349E-05	1.142E-07
TCDD	1.369E-10	1.009E-11	2.293E-09	1.892E-08	4.966E-11
PeCDD	3.305E-10	2.436E-11	5.537E-09	4.568E-08	1.199E-10
HxCDD	4.721E-10	3.480E-11	7.909E-09	6.525E-08	1.713E-10
pentachlorodibenzofuran	9.756E-10	7.191E-11	1.634E-08	1.348E-07	3.539E-10
tetrachlorodibenzofuran	6.378E-10	4.701E-11	1.068E-08	8.815E-08	2.314E-10
hexachlorodibenzofuran	6.287E-09	4.634E-10	1.053E-07	8.689E-07	2.281E-09
4-chlorophenyl methylsulfoxide	2.086E-06	1.538E-07	3.495E-05	2.883E-04	7.567E-07
4-chlorophenyl methylsulfone	2.691E-07	1.984E-08	4.508E-06	3.719E-05	9.762E-08
diisopropyl methylphosphonate	1.283E-09	9.457E-11	2.149E-08	1.773E-07	4.654E-10
dimethyl methylphosphonate	2.086E-08	1.538E-09	3.495E-07	2.883E-06	7.567E-09
dithiane	1.043E-09	7.688E-11	1.747E-08	1.441E-07	3.783E-10
malathion	8.448E-09	6.227E-10	1.415E-07	1.168E-06	3.064E-09
parathion	1.147E-09	8.455E-11	1.921E-08	1.585E-07	4.161E-10
particulate	4.070E-01	3.000E-02	6.818E+00	5.625E-01	1.476E-01
arsenic	8.637E-05	6.366E-06	1.447E-03	1.194E-02	3.133E-05
antimony	2.306E-04	1.700E-05	3.863E-03	3.187E-02	8.365E-05
barium	2.818E-04	2.077E-05	4.721E-03	3.895E-02	1.022E-04
beryllium	2.161E-06	1.593E-07	3.620E-05	2.987E-04	7.839E-07
cadmium	9.393E-05	6.924E-06	1.574E-03	1.298E-02	3.407E-05
chromium	8.555E-06	6.306E-07	1.433E-04	1.182E-03	3.103E-06
copper	3.100E-03	2.285E-04	5.193E-02	4.284E-01	1.125E-03
lead	2.989E-04	2.203E-05	5.007E-03	4.131E-02	1.084E-04
nickel	6.902E-05	5.087E-06	1.156E-03	9.539E-03	2.504E-05
silver	4.339E-06	3.198E-07	7.269E-05	5.997E-04	1.574E-06
thallium	8.637E-05	6.366E-06	1.447E-03	1.194E-02	3.133E-05
mercury	5.469E-05	4.030E-06	9.160E-04	7.557E-03	1.983E-05

TABLE . . DEPOSITION IMPACTS FROM SOI AT PARTICULATE DEP OF 0.04 GM/M2-YR - STAPLETON (1988)

COMPOUND	EMISSION RATE (G/SEC)	ANN. IMPACT COMPOUND DEPOSITION (GM/M2-YR)	RESULTANT SOIL CONC (MG/KG)	RESULTANT BIOMASS CONC (MG/KG)	RESULTANT SFC WATER CONC (MG/L)
endrin	6.216E-09	6.109E-10	1.388E-07	1.145E-06	3.006E-09
Isodrin	2.065E-08	2.029E-09	4.612E-07	3.805E-06	9.988E-09
bis (2-Ethylhexyl) phthalate	1.512E-04	1.486E-05	3.377E-03	2.786E-02	7.313E-05
Di-n-butylphthalate	2.039E-04	2.004E-05	4.554E-03	3.757E-02	9.862E-05
aldrin	3.644E-07	3.581E-08	8.139E-06	6.715E-05	1.762E-07
dieldrin	3.147E-07	3.093E-08	7.029E-06	5.799E-05	1.522E-07
4,4' - DDT	3.147E-07	3.093E-08	7.029E-06	5.799E-05	1.522E-07
4,4' - DDE	3.147E-07	3.093E-08	7.029E-06	5.799E-05	1.522E-07
TCDD	1.369E-10	1.345E-11	3.058E-09	2.523E-08	6.621E-11
PeCDD	3.305E-10	3.248E-11	7.382E-09	6.090E-08	1.599E-10
HxCDD	4.721E-10	4.640E-11	1.055E-08	8.700E-08	2.283E-10
pentachlorodibenzofuran	9.756E-10	9.588E-11	2.179E-08	1.798E-07	4.719E-10
tetrachlorodibenzofuran	6.378E-10	6.268E-11	1.425E-08	1.175E-07	3.085E-10
hexachlorodibenzofuran	6.287E-09	6.179E-10	1.404E-07	1.159E-06	3.041E-09
4-chlorophenyl methylsulfoxide	2.086E-06	2.050E-07	4.659E-05	3.844E-04	1.009E-06
4-chlorophenyl methylsulfone	2.691E-07	2.645E-08	6.011E-06	4.959E-05	1.302E-07
diisopropyl methylphosphonate	1.283E-09	1.261E-10	2.866E-08	2.364E-07	6.205E-10
dimethyl methylphosphonate	2.086E-08	2.050E-09	4.659E-07	3.844E-06	1.009E-08
dithiane	1.043E-09	1.025E-10	2.330E-08	1.922E-07	5.045E-10
malathion	8.448E-09	8.303E-10	1.887E-07	1.557E-06	4.086E-09
parathion	1.147E-09	1.127E-10	2.562E-08	2.114E-07	5.548E-10
particulate	4.070E-01	4.000E-02	9.091E+00	7.500E-01	1.969E-01
arsenic	8.637E-05	8.488E-06	1.929E-03	1.592E-02	4.177E-05
antimony	2.306E-04	2.266E-05	5.151E-03	4.249E-02	1.115E-04
barium	2.818E-04	2.770E-05	6.294E-03	5.193E-02	1.363E-04
beryllium	2.161E-06	2.124E-07	4.827E-05	3.982E-04	1.045E-06
cadmium	9.393E-05	9.231E-06	2.098E-03	1.731E-02	4.543E-05
chromium	8.555E-06	8.408E-07	1.911E-04	1.576E-03	4.138E-06
copper	3.100E-03	3.047E-04	6.924E-02	5.713E-01	1.499E-03
lead	2.989E-04	2.938E-05	6.676E-03	5.508E-02	1.446E-04
nickel	6.902E-05	6.783E-06	1.542E-03	1.272E-02	3.338E-05
silver	4.339E-06	4.264E-07	9.692E-05	7.996E-04	2.099E-06
thallium	8.637E-05	8.488E-06	1.929E-03	1.592E-02	4.177E-05
mercury	5.468E-05	5.374E-06	1.221E-03	1.008E-02	2.645E-05

TABLE - - DEPOSITION IMPACTS FROM SQI AT PARTICULATE DEP OF 0.05 GM/M2-YR - STAPLETON (1988)

COMPOUND	EMISSION RATE (G/SEC)	ANN. IMPACT COMPOUND DEPOSITION (GM/M2-YR)	RESULTANT SOIL CONC (MG/KG)	RESULTANT BIOMASS CONC (MG/KG)	RESULTANT SFC WATER CONC (MG/L)
endrin	6.216E-09	7.636E-10	1.736E-07	1.432E-06	3.758E-09
isodrin	2.065E-08	2.537E-09	5.766E-07	4.757E-06	1.248E-08
bis (2-Ethylhexyl) phthalate	1.512E-04	1.857E-05	4.222E-03	3.483E-02	9.141E-05
Di-n-butylphthalate	2.039E-04	2.505E-05	5.693E-03	4.697E-02	1.233E-04
aldrin	3.644E-07	4.477E-08	1.017E-05	8.394E-05	2.203E-07
dieldrin	3.147E-07	3.866E-08	8.787E-06	7.249E-05	1.903E-07
4,4' - DDT	3.147E-07	3.866E-08	8.787E-06	7.249E-05	1.903E-07
4,4' - DDE	3.147E-07	3.866E-08	8.787E-06	7.249E-05	1.903E-07
TCDD	1.369E-10	1.682E-11	3.822E-09	3.153E-08	8.277E-11
PeCDD	3.305E-10	4.060E-11	9.228E-09	7.613E-08	1.998E-10
HxCDD	4.721E-10	5.800E-11	1.318E-08	1.087E-07	2.854E-10
pentachlorodibenzofuran	9.756E-10	1.199E-10	2.724E-08	2.247E-07	5.898E-10
tetrachlorodibenzofuran	6.378E-10	7.835E-11	1.781E-08	1.469E-07	3.856E-10
hexachlorodibenzofuran	6.287E-09	7.724E-10	1.755E-07	1.448E-06	3.801E-09
4-chlorophenyl methylsulfoxide	2.086E-06	2.563E-07	5.824E-05	4.805E-04	1.261E-06
4-chlorophenyl methylsulfone	2.691E-07	3.306E-08	7.513E-06	6.199E-05	1.627E-07
diisopropyl methylphosphonate	1.283E-09	1.576E-10	3.582E-08	2.955E-07	7.757E-10
dimethyl methylphosphonate	2.086E-08	2.563E-09	5.824E-07	4.805E-06	1.261E-08
dithiane	1.043E-09	1.281E-10	2.912E-08	2.402E-07	6.306E-10
malathion	8.448E-09	1.036E-09	2.359E-07	1.946E-06	5.107E-09
parathion	1.147E-09	1.409E-10	3.202E-08	2.642E-07	6.935E-10
particulate	4.070E-01	5.000E-02	1.136E+01	9.375E+01	2.461E-01
arsenic	8.637E-05	1.061E-05	2.411E-03	1.989E-02	5.222E-05
antimony	2.306E-04	2.833E-05	6.438E-03	5.312E-02	1.394E-04
barium	2.818E-04	3.462E-05	7.868E-03	6.491E-02	1.704E-04
beryllium	2.161E-06	2.655E-07	6.034E-05	4.978E-04	1.306E-06
cadmium	9.393E-05	1.154E-05	2.623E-03	2.164E-02	5.679E-05
chromium	8.555E-06	1.051E-06	2.389E-04	1.971E-03	5.172E-06
copper	3.100E-03	3.808E-04	8.655E-02	7.141E-01	1.874E-03
lead	2.989E-04	3.672E-05	8.345E-03	6.885E-02	1.807E-04
nickel	6.902E-05	8.479E-06	1.927E-03	1.590E-02	4.173E-05
silver	4.339E-06	5.330E-07	1.211E-04	9.995E-04	2.623E-06
thallium	8.637E-05	1.061E-05	2.411E-03	1.989E-02	5.222E-05
mercury	5.468E-05	6.717E-06	1.527E-03	1.260E-02	3.306E-05

COMPOUND	EMISSION RATE (G/SEC)	ANN. IMPACT COMPOUND DEPOSITION (GM/M2-YR)	RESULTANT SOIL CONC (MG/KG)	RESULTANT BIOMASS CONC (MG/KG)	RESULTANT SFC WATER CONC (MG/L)
endrin	6.216E-09	9.164E-10	2.083E-07	1.718E-06	4.510E-09
isodrin	2.065E-08	3.044E-09	6.919E-07	5.708E-06	1.498E-08
bis (2-Ethylhexyl) phthalate	1.512E-04	2.229E-05	5.066E-03	4.179E-02	1.097E-04
Di-n-butylphthalate	2.039E-04	3.006E-05	6.832E-03	5.636E-02	1.479E-04
aldrin	3.644E-07	5.372E-08	1.221E-05	1.007E-04	2.644E-07
dieldrin	3.147E-07	4.639E-08	1.054E-05	8.699E-05	2.283E-07
4,4' - DDT	3.147E-07	4.639E-08	1.054E-05	8.699E-05	2.283E-07
4,4' - DDE	3.147E-07	4.639E-08	1.054E-05	8.699E-05	2.283E-07
TCDD	1.369E-10	2.018E-11	4.587E-09	3.784E-08	9.932E-11
PeCDD	3.305E-10	4.872E-11	1.107E-08	9.135E-08	2.398E-10
HxCDD	4.721E-10	6.960E-11	1.582E-08	1.305E-07	3.425E-10
pentachlorodibenzofuran	9.756E-10	1.438E-10	3.269E-08	2.697E-07	7.078E-10
tetrachlorodibenzofuran	6.378E-10	9.402E-11	2.137E-08	1.763E-07	4.627E-10
hexachlorodibenzofuran	6.287E-09	9.268E-10	2.106E-07	1.738E-06	4.561E-09
4-chlorophenyl methylsulfoxide	2.086E-06	3.075E-07	6.989E-05	5.766E-04	1.513E-06
4-chlorophenyl methylsulfone	2.691E-07	3.967E-08	9.016E-06	7.438E-05	1.952E-07
diisopropyl methylphosphonate	1.283E-09	1.891E-10	4.299E-08	3.546E-07	9.308E-10
dimethyl methylphosphonate	2.086E-08	3.075E-09	6.989E-07	5.766E-06	1.513E-08
dithiane	1.043E-09	1.538E-10	3.495E-08	2.883E-07	7.567E-10
malathion	8.448E-09	1.245E-09	2.830E-07	2.335E-06	6.129E-09
parathion	1.147E-09	1.691E-10	3.843E-08	3.170E-07	8.321E-10
particulate	4.070E-01	6.000E-02	1.364E+01	1.125E+02	2.953E-01
arsenic	8.637E-05	1.273E-05	2.894E-03	2.387E-02	6.266E-05
antimony	2.306E-04	3.400E-05	7.726E-03	6.374E-02	1.673E-04
barium	2.818E-04	4.154E-05	9.442E-03	7.789E-02	2.044E-04
beryllium	2.161E-06	3.186E-07	7.240E-05	5.973E-04	1.568E-06
cadmium	9.393E-05	1.385E-05	3.147E-03	2.596E-02	6.815E-05
chromium	8.555E-06	1.261E-06	2.866E-04	2.365E-03	6.207E-06
copper	3.100E-03	4.570E-04	1.039E-01	8.569E-01	2.249E-03
lead	2.989E-04	4.406E-05	1.001E-02	8.262E-02	2.168E-04
nickel	6.902E-05	1.017E-05	2.312E-03	1.908E-02	5.007E-05
silver	4.339E-06	6.397E-07	1.454E-04	1.199E-03	3.148E-06
thallium	8.637E-05	1.273E-05	2.894E-03	2.387E-02	6.266E-05
mercury	5.468E-05	8.061E-06	1.832E-03	1.511E-02	3.967E-05

TABLE - - DEPOSITION IMPACTS FROM SQI AT PARTICULATE DEP OF 0.11 GM/M2-YR - STAPLETON (1988)

COMPOUND	EMISSION RATE (G/SEC)	ANN. IMPACT COMPOUND DEPOSITION (GM/M2-YR)	RESULTANT SOIL CONC (MG/KG)	RESULTANT BIOMASS CONC (MG/KG)	RESULTANT SFC WATER CONC (MG/L)
endrin	6.216E-09	1.680E-09	3.818E-07	3.150E-06	8.268E-09
isodrin	2.065E-08	5.581E-09	1.268E-06	1.046E-05	2.747E-08
bis (2-Ethylhexyl) phthalate	1.512E-04	4.086E-05	9.287E-03	7.662E-02	2.011E-04
Di-n-butylphthalate	2.039E-04	5.511E-05	1.252E-02	1.033E-01	2.712E-04
aldrin	3.644E-07	9.849E-08	2.238E-05	1.847E-04	4.847E-07
dieldrin	3.147E-07	8.505E-08	1.933E-05	1.595E-04	4.186E-07
4,4' - DDT	3.147E-07	8.505E-08	1.933E-05	1.595E-04	4.186E-07
4,4' - DDE	3.147E-07	8.505E-08	1.933E-05	1.595E-04	4.186E-07
TCDD	1.369E-10	3.700E-11	8.409E-09	6.938E-08	1.821E-10
PeCDD	3.305E-10	8.932E-11	2.030E-08	1.675E-07	4.396E-10
HxCDD	4.721E-10	1.276E-10	2.900E-08	2.392E-07	6.279E-10
pentachlorodibenzofuran	9.756E-10	2.637E-10	5.993E-08	4.944E-07	1.298E-09
tetrachlorodibenzofuran	6.378E-10	1.724E-10	3.918E-08	3.232E-07	8.483E-10
hexachlorodibenzofuran	6.287E-09	1.699E-09	3.862E-07	3.186E-06	8.362E-09
4-chlorophenyl methylsulfoxide	2.066E-06	5.638E-07	1.281E-04	1.057E-03	2.775E-06
4-chlorophenyl methylsulfone	2.691E-07	7.273E-08	1.653E-05	1.364E-04	3.57xE-07
diisopropyl methylphosphonate	1.283E-09	3.468E-10	7.881E-08	6.502E-07	1.706E-09
dimethyl methylphosphonate	2.066E-08	5.638E-09	1.281E-06	1.057E-05	2.775E-08
dithiane	1.043E-09	2.819E-10	6.407E-08	5.285E-07	1.387E-09
malathion	8.448E-09	2.283E-09	5.189E-07	4.281E-06	1.124E-08
parathion	1.147E-09	3.100E-10	7.045E-08	5.813E-07	1.526E-09
particulate	4.070E-01	1.100E-01	2.500E+01	2.063E+02	5.413E-01
arsenic	8.637E-05	2.334E-05	5.305E-03	4.377E-02	1.149E-04
antimony	2.306E-04	6.232E-05	1.416E-02	1.169E-01	3.067E-04
barium	2.818E-04	7.616E-05	1.731E-02	1.428E-01	3.748E-04
beryllium	2.161E-06	5.841E-07	1.327E-04	1.095E-03	2.874E-06
cadmium	9.393E-05	2.539E-05	5.770E-03	4.760E-02	1.249E-04
chromium	8.555E-06	2.312E-06	5.255E-04	4.335E-03	1.138E-05
copper	3.100E-03	8.378E-04	1.904E-01	1.571E+00	4.123E-03
lead	2.989E-04	8.078E-05	1.836E-02	1.515E-01	3.976E-04
nickel	6.902E-05	1.865E-05	4.240E-03	3.498E-02	9.180E-05
silver	4.339E-06	1.173E-06	2.665E-04	2.199E-03	5.771E-06
thallium	8.637E-05	2.334E-05	5.305E-03	4.377E-02	1.149E-04
mercury	5.468E-05	1.478E-05	3.359E-03	2.771E-02	7.273E-05

TABLE - - DEPOSITION IMPACTS FROM SQI AT PARTICULATE DEP OF 0.36 GM/M2-YR - STAPLETON (1988)

COMPOUND	EMISSION RATE (G/SEC)	ANN. IMPACT COMPOUND DEPOSITION (GM/M2-YR)	RESULTANT SOIL CONC (MG/KG)	RESULTANT BIOMASS CONC (MG/KG)	RESULTANT SPEC WATER CONC (MG/L)
endrin	6.216E-09	5.498E-09	1.250E-06	1.031E-05	2.706E-08
isodrin	2.065E-08	1.827E-08	4.151E-06	3.425E-05	8.989E-08
bis (2-Ethylhexyl) phthalate	1.512E-04	1.337E-04	3.040E-02	2.508E-01	6.582E-04
Di-n-butylphthalate	2.039E-04	1.804E-04	4.099E-02	3.382E-01	8.876E-04
aldrin	3.644E-07	3.223E-07	7.325E-05	6.043E-04	1.586E-06
dieldrin	3.147E-07	2.784E-07	6.326E-05	5.219E-04	1.370E-06
4,4' - DDT	3.147E-07	2.784E-07	6.326E-05	5.219E-04	1.370E-06
4,4' - DDE	3.147E-07	2.784E-07	6.326E-05	5.219E-04	1.370E-06
TCDD	1.369E-10	1.211E-10	2.752E-08	2.270E-07	5.959E-10
PeCDD	3.305E-10	2.923E-10	6.644E-08	5.481E-07	1.439E-09
HxCDD	4.721E-10	4.176E-10	9.491E-08	7.830E-07	2.055E-09
pentachlorodibenzofuran	9.756E-10	8.629E-10	1.961E-07	1.618E-06	4.247E-09
tetrachlorodibenzofuran	6.378E-10	5.641E-10	1.282E-07	1.058E-06	2.776E-09
hexachlorodibenzofuran	6.287E-09	5.561E-09	1.264E-06	1.043E-05	2.737E-08
4-chlorophenyl methylsulfoxide	2.086E-06	1.845E-06	4.193E-04	3.660E-03	9.080E-06
4-chlorophenyl methylsulfone	2.691E-07	2.380E-07	5.410E-05	4.463E-04	1.171E-06
diisopropyl methylphosphonate	1.283E-09	1.135E-09	2.579E-07	2.128E-06	5.585E-09
dimethyl methylphosphonate	2.086E-08	1.845E-08	4.193E-06	3.660E-05	9.080E-08
dithiane	1.043E-09	9.226E-10	2.097E-07	1.730E-06	4.540E-09
malathion	8.448E-09	7.472E-09	1.698E-06	1.401E-05	3.677E-08
parathion	1.147E-09	1.015E-09	2.306E-07	1.902E-06	4.993E-09
particulate	4.070E-01	3.600E-01	8.182E+01	6.730E+02	1.772E+00
arsenic	8.637E-05	7.640E-05	1.736E-02	1.432E-01	3.760E-04
antimony	2.306E-04	2.040E-04	4.636E-02	3.824E-01	1.004E-03
barium	2.818E-04	2.493E-04	5.665E-02	4.674E-01	1.227E-03
beryllium	2.161E-06	1.911E-06	4.344E-04	3.584E-03	9.407E-06
cadmium	9.393E-05	8.308E-05	1.888E-02	1.558E-01	4.089E-04
chromium	8.555E-06	7.567E-06	1.720E-03	1.619E-02	3.724E-05
copper	3.100E-03	-2.742E-03	6.232E-01	5.161E+00	1.349E-02
lead	2.989E-04	2.646E-04	6.009E-02	4.957E-01	1.301E-03
nickel	6.902E-05	6.105E-05	1.387E-02	1.145E-01	3.004E-04
silver	4.339E-06	3.838E-06	8.723E-04	7.196E-03	1.889E-05
thallium	8.637E-05	7.640E-05	1.736E-02	1.432E-01	3.760E-04
mercury	5.468E-05	4.837E-05	1.099E-02	9.069E-02	2.380E-04

TABLE - - DEPOSITION IMPACTS FROM SOI AT PARTICULATE DEP OF 0.61 GM/M2-YR - STAPLETON (1988)

COMPOUND	EMISSION RATE (G/SEC)	ANN. IMPACT COMPOUND DEPOSITION (GM/M2-YR)	RESULTANT SOIL CONC (MG/KG)	RESULTANT BIOMASS CONC (MG/KG)	RESULTANT SFC WATER CONC (MG/L)
endrin	6.216E-09	9.316E-09	2.117E-06	1.747E-05	4.585E-08
isodrin	2.065E-08	3.095E-08	7.034E-06	5.803E-05	1.523E-07
bis (2-Ethylhexyl) phthalate	1.512E-04	2.266E-04	5.150E-02	4.249E-01	1.115E-03
Di-n-butylphthalate	2.039E-04	3.056E-04	6.945E-02	5.730E-01	1.504E-03
aldrin	3.644E-07	5.462E-07	1.241E-04	1.024E-03	2.688E-06
dieldrin	3.147E-07	4.717E-07	1.072E-04	8.844E-04	2.321E-06
4,4' - DDT	3.147E-07	4.717E-07	1.072E-04	8.844E-04	2.321E-06
4,4' - DDE	3.147E-07	4.717E-07	1.072E-04	8.844E-04	2.321E-06
TCDD	1.369E-10	2.052E-10	4.663E-08	3.847E-07	1.010E-09
PeCDD	3.305E-10	4.953E-10	1.126E-07	9.288E-07	2.438E-09
HxCDD	4.721E-10	7.076E-10	1.608E-07	1.327E-06	3.482E-09
pentachlorodibenzofuran	9.756E-10	1.462E-09	3.323E-07	2.742E-06	7.196E-09
tetrachlorodibenzofuran	6.378E-10	9.559E-10	2.173E-07	1.792E-06	4.704E-09
hexachlorodibenzofuran	6.287E-09	9.423E-09	2.142E-06	1.767E-05	4.637E-08
4-chlorophenyl methylsulfoxide	2.086E-06	3.126E-06	7.106E-04	5.862E-03	1.539E-05
4-chlorophenyl methylsulfone	2.691E-07	4.033E-07	9.166E-05	7.562E-04	1.985E-06
diisopropyl methylphosphonate	1.283E-09	1.923E-09	4.370E-07	3.605E-06	9.463E-09
dimethyl methylphosphonate	2.086E-08	3.126E-08	7.106E-06	5.862E-05	1.539E-07
dithiane	1.043E-09	1.563E-09	3.553E-07	2.931E-06	7.693E-09
malathion	8.448E-09	1.266E-08	2.878E-06	2.374E-05	6.231E-08
parathion	1.147E-09	1.719E-09	3.907E-07	3.223E-06	8.460E-09
particulate	4.070E-01	6.100E-01	1.386E+02	1.144E+03	3.002E+00
arsenic	8.637E-05	1.294E-04	2.942E-02	2.427E-01	6.371E-04
antimony	2.306E-04	3.456E-04	7.855E-02	6.480E-01	1.701E-03
barium	2.818E-04	4.224E-04	9.599E-02	7.919E-01	2.079E-03
beryllium	2.161E-06	3.239E-06	7.361E-04	6.073E-03	1.594E-05
cadmium	9.393E-05	1.408E-04	3.200E-02	2.640E-01	6.928E-04
chromium	8.555E-06	1.282E-05	2.914E-03	2.404E-02	6.310E-05
copper	3.100E-03	4.646E-03	1.056E+00	8.712E+00	2.287E-02
lead	2.989E-04	4.480E-04	1.018E-01	8.400E-01	2.205E-03
nickel	6.902E-05	1.034E-04	2.351E-02	1.940E-01	5.091E-04
silver	4.339E-06	6.503E-06	1.478E-03	1.219E-02	3.200E-05
thallium	8.637E-05	1.294E-04	2.942E-02	2.427E-01	6.371E-04
mercury	5.468E-05	8.195E-05	1.863E-02	1.537E-01	4.033E-04

TABLE . - DEPOSITION IMPACTS FROM SQI AT PARTICULATE DEP OF 0.86 GM/M2-YR - STAPLETON (1988)

COMPOUND	EMISSION RATE (G/SEC)	ANN. IMPACT COMPOUND DEPOSITION (GM/M2-YR)	RESULTANT SOIL CONC (MG/KG)	RESULTANT BIOMASS CONC (MG/KG)	RESULTANT SFC WATER CONC (MG/L)
endrin	6.216E-09	1.313E-08	2.985E-06	2.463E-05	6.464E-08
isodrin	2.065E-08	4.363E-08	9.917E-06	8.181E-05	2.147E-07
bis (2-Ethylhexyl) phthalate	1.512E-04	3.195E-04	7.261E-02	5.990E-01	1.572E-03
Di-n-butylphthalate	2.039E-04	4.308E-04	9.792E-02	8.078E-01	2.120E-03
aldrin	3.644E-07	7.700E-07	1.750E-04	1.444E-03	3.789E-06
dieldrin	3.147E-07	6.650E-07	1.511E-04	1.247E-03	3.272E-06
4,4' - DDT	3.147E-07	6.650E-07	1.511E-06	1.247E-03	3.272E-06
4,4' - DDE	3.147E-07	6.650E-07	1.511E-04	1.247E-03	3.272E-06
TCDD	1.369E-10	2.893E-10	6.574E-08	5.424E-07	1.424E-09
PeCDD	3.305E-10	6.984E-10	1.587E-07	1.309E-06	3.437E-09
HxCDD	4.721E-10	9.976E-10	2.267E-07	1.870E-06	4.909E-09
pentachlorodibenzofuran	9.756E-10	2.061E-09	4.685E-07	3.865E-06	1.015E-08
tetrachlorodibenzofuran	6.378E-10	1.348E-09	3.063E-07	2.527E-06	6.632E-09
hexachlorodibenzofuran	6.287E-09	1.328E-08	3.019E-06	2.491E-05	6.538E-08
4-chlorophenyl methylsulfoxide	2.086E-06	4.408E-06	1.002E-03	8.265E-03	2.169E-05
4-chlorophenyl methylsulfone	2.691E-07	5.686E-07	1.292E-04	1.066E-03	2.798E-06
diisopropyl methylphosphonate	1.283E-09	2.711E-09	6.161E-07	5.083E-06	1.334E-08
dimethyl methylphosphonate	2.086E-08	4.408E-08	1.002E-05	8.265E-05	2.169E-07
dithiane	1.043E-09	2.204E-09	5.009E-07	4.132E-06	1.085E-08
malathion	8.448E-09	1.785E-08	4.057E-06	3.347E-05	8.785E-08
parathion	1.147E-09	2.424E-09	5.508E-07	4.544E-06	1.193E-08
particulate	4.070E-01	8.600E-01	1.955E+02	1.612E+03	4.232E+00
arsenic	8.637E-05	1.825E-04	4.148E-02	3.422E-01	8.981E-04
antimony	2.306E-04	4.873E-04	1.107E-01	9.136E-01	2.398E-03
barium	2.818E-04	5.954E-04	1.353E-01	1.116E+00	2.930E-03
beryllium	2.161E-06	4.566E-06	1.038E-03	8.562E-03	2.247E-05
cadmium	9.393E-05	1.985E-04	4.511E-02	3.721E-01	9.768E-04
chromium	8.555E-06	1.808E-05	4.108E-03	3.389E-02	8.896E-05
copper	3.100E-03	6.550E-03	1.489E+00	1.228E+01	3.224E-02
lead	2.989E-04	6.316E-04	1.435E-01	1.184E+00	3.108E-03
nickel	6.902E-05	1.458E-04	3.315E-02	2.735E-01	7.177E-04
silver	4.339E-06	9.168E-06	2.084E-03	1.719E-02	4.512E-05
thallium	8.637E-05	1.825E-04	4.148E-02	3.422E-01	8.981E-04
mercury	5.468E-05	1.155E-04	2.626E-02	2.166E-01	5.686E-04

TABLE - - MAXIMUM DEPOSITION IMPACTS FROM SQI ON ON-SITE RECEPTORS USING - STAPLETON (1988)

COMPOUND	EMISSION RATE (G/SEC)	ANN. IMPACT COMPOUND DEPOSITION (GM/M2-YR)	RESULTANT SOIL CONC (MG/KG)	RESULTANT BIOMASS CONC (MG/KG)	RESULTANT SP WATER CONC (MG/L)
endrin	6.216E-09	1.858E-08	4.222E-06	3.483E-05	9.142E-08
isodrin	2.065E-08	6.171E-08	1.403E-05	1.157E-04	3.037E-07
bis (2-Ethylhexyl) phthalate	1.512E-04	4.519E-04	1.027E-01	8.473E-01	2.224E-03
Di-n-butylphthalate	2.039E-04	6.094E-04	1.385E-01	1.143E+00	2.999E-03
aldrin	3.644E-07	1.089E-06	2.475E-04	2.042E-03	5.359E-06
dieldrin	3.147E-07	9.405E-07	2.137E-04	1.763E-03	4.628E-06
4,4' - DDT	3.147E-07	9.405E-07	2.137E-04	1.763E-03	4.628E-06
4,4' - DDE	3.147E-07	9.405E-07	2.137E-04	1.763E-03	4.628E-06
TCDD	1.369E-10	4.091E-10	9.298E-08	7.671E-07	2.013E-09
PeCDD	3.305E-10	9.877E-10	2.245E-07	1.852E-06	4.861E-09
HxCDD	4.721E-10	1.411E-09	3.207E-07	2.645E-06	6.945E-09
pentachlorodibenzofuran	9.756E-10	2.916E-09	6.626E-07	5.467E-06	1.435E-08
tetrachlorodibenzofuran	6.378E-10	1.906E-09	4.332E-07	3.574E-06	9.380E-09
hexachlorodibenzofuran	6.287E-09	1.879E-08	4.270E-06	3.523E-05	9.247E-08
4-chlorophenyl methylsulfoxide	2.086E-06	6.234E-06	1.417E-03	1.169E-02	3.068E-05
4-chlorophenyl methylsulfone	2.691E-07	8.042E-07	1.828E-04	1.508E-03	3.958E-06
diisopropyl methylphosphonate	1.283E-09	3.834E-09	8.714E-07	7.189E-06	1.887E-08
dimethyl methylphosphonate	2.086E-08	6.234E-08	1.417E-05	1.169E-04	3.068E-07
dithiane	1.043E-09	3.117E-09	7.084E-07	5.844E-06	1.534E-08
malathion	8.448E-09	2.525E-08	5.738E-06	4.734E-05	1.242E-07
parathion	1.147E-09	3.428E-09	7.791E-07	6.427E-06	1.687E-08
particulate	4.070E-01	1.216E+00	2.764E+02	2.281E+03	5.986E+00
arsenic	8.637E-05	2.581E-04	5.866E-02	4.840E-01	1.270E-03
antimony	2.306E-04	6.892E-04	1.566E-01	1.292E+00	3.392E-03
barium	2.818E-04	8.422E-04	1.914E-01	1.579E+00	4.145E-03
beryllium	2.161E-06	6.458E-06	1.468E-03	1.211E-02	3.178E-05
cadmium	9.393E-05	2.807E-04	6.380E-02	5.263E-01	1.381E-03
chromium	8.555E-06	2.557E-05	5.811E-03	4.794E-02	1.258E-04
copper	3.100E-03	9.265E-03	2.106E+00	1.737E+01	4.559E-02
lead	2.989E-04	8.935E-04	2.030E-01	1.675E+00	4.396E-03
nickel	6.902E-05	2.063E-04	4.688E-02	3.868E-01	1.015E-03
silver	4.339E-06	1.297E-05	2.947E-03	2.431E-02	6.382E-05
thallium	8.637E-05	2.581E-04	5.866E-02	4.840E-01	1.270E-03
mercury	5.468E-05	1.634E-04	3.714E-02	3.064E-01	8.042E-04

END
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